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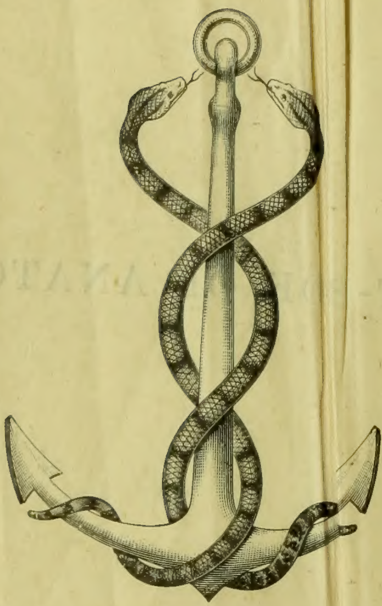
TEXT-BOOK OF ANATOMY.



NUNQUAM ALIUD NATURA, ALIUD SAPIEN DICIT

TEXT-BOOK

OF

ANATOMY

EDITED BY

D. J. CUNNINGHAM, F.R.S.

M.D. (EDIN. ET DUBL.), D.SC., LL.D. (GLASG. ET ST. AND.), D.C.L. (OXON.)
PROFESSOR OF ANATOMY AND CHIRURGERY, TRINITY COLLEGE, DUBLIN

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TO

Sir William Turner, K.C.B.

F.R.S., M.B., LL.D., D.C.L., D.SC.,

IN RECOGNITION OF

HIS EMINENCE AS AN ANATOMIST

AND HIS INFLUENCE AS A TEACHER

THIS VOLUME

IS DEDICATED

BY THOSE OF HIS FORMER PUPILS AND ASSISTANTS

WHO HAVE CONTRIBUTED

TO ITS PAGES

PREFACE.

THE form which this book has taken expresses the desire of those who have contributed the various sections to produce something which they might dedicate to their former teacher and master, Sir William Turner. With one exception, all the contributors have studied under Sir William Turner, and all but two have for longer or shorter periods acted as his Assistants. Bound together by this common tie, and animated by affection and reverence for their great master, they have sought to produce a book worthy of him whose teaching it so largely reflects, and if this object has not been attained it is not for want of will, but of power, on the part of the writers.

In the preparation of a work such as this it is no easy matter to prevent overlapping of the different articles and to keep the various sections in harmony with each other. Yet in this direction it is believed that a fair amount of success has been attained. Differences of opinion on particular points were bound to arise, but the Editor found in those concerned the greatest readiness to come to a mutual understanding, and he is deeply grateful to his colleagues for the manner in which they endeavoured to lighten his work and assist him in his task. Of course when totally different views were held by two authors on a matter which had to be dealt with in two sections, no serious attempt was made to urge these writers to qualify their statements so as to produce an apparent agreement. It was felt that if this were done the individuality of the author, which forms a characteristic feature of each article as it stands, would thereby be damaged; and further, it was believed that the same question discussed from two different points of view could not fail to be of advantage to the reader. At the same time it is right to state that the places in which a divergence of opinion appears are very few, and taking into account that nine writers have co-operated with the Editor, a remarkable degree of harmony in the treatment of the different sections has been obtained.

The recent introduction of Formalin as a hardening and preserving reagent imposed an especially arduous duty upon those writers who had undertaken the chapters dealing with the thoracic and abdominal viscera. The possibilities for establishing a more accurate topography and of improving our conception of the forms assumed by the viscera under different conditions have by this means been greatly extended; and in preparing the sections which treat of these organs the writers have taken full advantage of the new method. Much, therefore, which appears in this book on the topographical relations of the viscera departs considerably from the older and more conventional descriptions hitherto in vogue.

The arrangement of the matter treated in the following pages is very much the same as that adopted in the various courses of lectures delivered in the schools from which the different sections of the work have emanated. The first chapter is

devoted to the general principles and elementary facts of Embryology. Then follow, in an order best suited for the student, the chapters dealing with the various systems of organs; whilst the last seventy-five pages are used for the purpose of applying the information conveyed in the preceding part of the book to the practice of medicine and surgery. Each chapter is more or less complete in itself, although an effort has been made to weld them all into one consistent whole.

The numerous illustrations which appear in the text are all new in the sense that in no case has an old drawing or an old block been used. Further, the vast majority of the illustrations are new in the sense that they are original. The very few that are not have been taken from monographs dealing with the subjects so illustrated, and in every case the source from which these have been obtained is acknowledged in the text. The drawings for each section were prepared under the personal supervision of its author, and, with the exception of the figures in two chapters, they are the work of Mr. J. T. Murray. This talented artist has devoted much time to the undertaking, and the reader can judge for himself the success which has attended his efforts. The Editor cannot sufficiently express his indebtedness to Mr. Murray for the great technical skill and the patience which he brought to bear upon this extremely trying and difficult work. The chapter on Osteology has been illustrated by Mr. W. C. Stevens; that upon Embryology by the authors themselves; whilst the microscopical drawings in the section on the Brain and Cord were executed by Mr. Wm. Cathie. It is also necessary to mention that the coloured outlines representing the attachments of the muscles on the figures of the bones were mapped in by Professor A. M. Paterson.

The Editor has to thank his former Assistant, Professor A. F. Dixon of Cardiff, for much help in the correction of the proofs.

Trinity College, Dublin,
June 1902.

LIST OF CONTRIBUTORS.

AMBROSE BIRMINGHAM, M.D., F.R.C.S.I.,
Professor of Anatomy, Catholic University School of Medicine, Dublin.
(*The Digestive System.*)

D. J. CUNNINGHAM, M.D., F.R.S.,
Professor of Anatomy and Chirurgery, University of Dublin.
(*The Brain and Spinal Cord*, *The Respiratory System*, *The Ductless Glands.*)

A. FRANCIS DIXON, M.B., D.Sc. (Dubl.),
Professor of Anatomy, University College, Cardiff.
(*The Urogenital System.*)

DAVID HEPBURN, M.D., F.R.S.E.,
Lecturer on Regional Anatomy, University of Edinburgh.
(*Arthrology.*)

ROBERT HOWDEN, M.A., M.B.,
Professor of Anatomy, University of Durham.
(*The Organs of Sense and the Integument.*)

A. M. PATERSON, M.D.,
Professor of Anatomy, University College, Liverpool.
(*Myology*, *The Spinal and Cranial Nerves*, *The Sympathetic Nervous System.*)

ARTHUR ROBINSON, M.D.,
Professor of Anatomy, King's College, London.
(*General Embryology*, *The Vascular System.*)

HAROLD J. STILES, M.B., F.R.C.S. Ed.,
Surgeon to the Royal Hospital for Sick Children, Edinburgh.
(*Surface and Surgical Anatomy.*)

ARTHUR THOMSON, M.A., M.B.,
Professor of Human Anatomy, University of Oxford.
(*Osteology.*)

A. H. YOUNG, M.B., F.R.C.S.,
Professor of Anatomy, The Owens College, Manchester.
(*General Embryology*, *The Vascular System.*)

The Index is the work of Dr. T. W. P. Lawrence.

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CORRIGENDA.

In line 10 from the top of page 144, *read* "apertura pyriformis" *for* "apertura pyriforme."

FIG. 340, page 457.—*For* "Spinal root of trigeminal nerve," *read* "Funiculus cuneatus"; and *for* "Direct cerebellar tract," *read* "Spinal root of trigeminal nerve."

FIG. 348, page 468.—*For* "Postero-interior lobule," *read* "Postero-inferior lobule."

FIG. 369, page 497.—*For* "ANTR. COM.," *read* "POSTR. COM."

TEXT-BOOK OF ANATOMY.

TEXT-BOOK OF ANATOMY.

INTRODUCTION.

ANATOMY is a comprehensive term, which includes several closely related branches of study. Primarily it is employed to indicate the study of the several parts which build up the body, and the relationship which these present to each other. But during the period of its existence the individual exhibits many structural changes: its structure is not the same at all stages of its life. The ovum or starting-point of every individual is very different from the finished organism as represented by the adult, and the series of changes through which the organism passes until its structure is perfected and full growth is attained constitute the study of **development**. The general term "development" includes not only the various and striking structural changes which occur during the intrauterine life of the individual, to the study of which the term **embryology** is more specially applied, but also many growth processes which occur after birth, such as the later stages in the ossification and growth of the bones, the eruption of the two series of teeth, the adjustment of the vascular system to its new requirements, etc. The actual observation of the processes by which the parts of the body are gradually formed, and of the structural arrangements by means of which a temporary connection is established between the ovum and the mother, through which an interchange of nutritive and other matters between the two takes place, renders embryology one of the most interesting of all the departments of anatomy. The term **ontogeny** is also used to denote the development of the individual. There is, however, another form of development, slower, but just as certain in its processes, which affects not only the individual, but every member of the animal group collectively to which it belongs. The theory of descent or evolution leads us to believe that between man of the present day and his remote ancestors there is a wide structural gap, which, if the geological record were perfect, would be seen to be completely occupied by long-lost intermediate forms. In the process of evolution, therefore, structural changes have gradually taken place, which have modified the entire race. A more or less close or remote blood-relationship links together all the members of the animal kingdom. These evolutionary phases constitute the ancestral history or **phylogeny** of the individual. Ontogeny and phylogeny are intertwined in a remarkable manner, and present certain extraordinary relationships. In other words, the ancestral evolutionary development appears to be so stamped upon an individual that it repeats certain of the phylogenetic stages with more or less clearness during the process of its own individual development. Thus at an early period in the embryology of man we recognise evanescent gill-slits comparable with those of a fish, whilst a study of the development of his heart shows that it passes

through transitory structural conditions in many respects similar to the permanent condition of the heart in certain of the lower animals. It is in connexion with this that the phrase has arisen that every animal in its individual development or ontogeny climbs up its own genealogical tree: a saying which, taking it even in the broadest sense, is only partially true.

The higher conceptions of anatomy, which are obtained by taking a general survey of the structural aspects of the entire animal kingdom, constitute **morphology**. The morphologist investigates the laws of form and structure, and in his generalisations he gives attention to detail only in so far as this is necessary for the proper establishment of his views. The knowledge of anatomy which is required by the student of medicine is different. It is essentially one of detail, and often details important from the practical and utilitarian points of view have little or no morphological value. This want of balance in the interest attached to anatomical facts, according to the aspect from which they are examined, so far from being unfortunate, affords the teacher the means of making the study of anatomy at once fascinating and attractive. Almost every fact which is brought under the notice of the student can be accompanied by a morphological or a practical application. This it is that lightens a study which, presented to the student of medicine in any other way, would be at once dry and tedious.

Certain terms employed in morphology require early and definite explanation. These are homology, serial homology, and homoplasy. The same organ repeated in two different animals is said to present a case of **homology**. But this morphological identity between these two organs must be proved beyond dispute before the homology between them can be allowed. In deciding this identity the great and essential test is that the two organs in question should have a similar developmental origin. Thus the fore-limb of a quadruped is homologous with the upper limb of man; the puny collar-bone of a tiger, the fibrous thread which is the only representative of this bone in the horse, and the strongly marked clavicle of the ape or man, are all, strictly speaking, homologous with each other. Homologous organs in different animals usually present a similar position and a similar structure, but not invariably so. It is not uncommon for a muscle to wander somewhat from its original position, and many cases could be quoted in which parts have become completely transformed in structure, either from disuse or for the purpose of meeting some special demand in the animal economy. In the study of the muscles and ligaments instances of this will be brought under the notice of the reader. Identity or correspondence in the function performed by two organs in two different animals is not taken into consideration in deciding questions of homology. The gills of a fish and the lungs of a higher vertebrate perform very much the same physiological office, and yet they are not homologous. The term **analogy** is often used to express functional correspondence of this kind. Often organs which perform totally different functions are yet perfectly homologous. Thus the wing of a bat or the wing of a bird, both of which are subservient to flight, are homologous with the upper limb of man, the office of which is the different one of prehension.

In the construction of vertebrates and certain other animal groups a series of similar parts are repeated along a longitudinal axis, one after the other. Thus the series of vertebræ which build up the backbone, the series of ribs which gird round either side of the chest, the series of intercostal muscles which fill up the intervals between the ribs, the series of nerves which arise from the brain and spinal cord, are all examples of this. An animal exhibiting such a condition of parts is said to present the **segmental type** of organisation, and in the early stages of development this segmentation is much more strongly marked, and is to be seen in parts which

subsequently lose all trace of such a subdivision. The parts thus repeated are said to be **serially homologous.** But there are other instances of serial homology besides those which are manifestly produced by segmentation. The upper limb is serially homologous with the lower limb: each is composed of parts which, to a large extent, are repeated in the other, and the correct adjustment of this comparison between the several parts of the upper and lower limbs constitutes one of the most difficult and yet interesting problems of morphology.

Homoplasy is a term which has been introduced to express a form of correspondence between organs in different animals which cannot be included under the term homology. Two animal groups, which originally have sprung from the same stem-form, may independently develop a similar structural character which is altogether absent in the ancestor common to both. Thus the common ancestor of man and the carnivora in all probability possessed a smooth brain, and yet the human brain and the carnivore brain are both richly convoluted. Not only this, but certain anatomists seek to reconcile the convolutionary pattern of the one with the convolutionary pattern of the other. What correspondence there is does not constitute a case of homology, because there is no community of origin, but it falls under the term "homoplasy." Another example is afforded by the heart of the mammal and that of the bird. In both of these groups the ventricular portion of the heart consists of a right and a left chamber, and yet these chambers in the one are not homologous with the corresponding chambers in the other, because the common ancestor from which both have sprung possessed a heart with a single ventricular cavity, and the double-chambered condition has been a subsequent and independent development in the two groups.

Systematic Anatomy.—The human body is composed of a combination of several systems of organs, and the several parts of each system not only present a certain similarity in structure, but also fulfil special functions. Thus we have—

1. The *skeletal system,* composed of the bones and certain cartilaginous and membranous parts associated with them, the study of which is known as **osteology.**

2. The *articulatory system,* which includes the joints or articulations, the study of which is termed **arthrology.**

3. The *muscular system,* comprising the muscles, the study of which constitutes **myology.**

4. The *nervous system,* in which are included the brain, the spinal cord, the spinal and cranial ganglia, the sympathetic ganglia, and the various nerves proceeding from and entering these. The study of these parts is expressed by the term **neurology.** In this system the organs of sense may also be included.

5. The *vascular* and *lymphatic* system, including the heart, blood-vessels, the lymphatic vessels, and the lymphatic glands. **Angeiology** is the term applied to the study of this system.

6. The *respiratory system,* in which we place the lungs, windpipe, and larynx.

7. The *digestive system,* which consists of the alimentary canal and its associated glands and parts, such as the tongue, teeth, liver, pancreas, etc.

8. The *urogenital system,* composed of the urinary organs and the reproductive organs—the latter differing in the two sexes.

The term **splanchnology** denotes the study of the organs included in the respiratory, digestive, and genito-urinary systems.

9. The *integumentary system,* consisting of the skin, nails, hair, etc.

These numerous organs which form the various systems are themselves built up of tissues, the ultimate elements of which can only be studied by the aid of the microscope. The study of these elements and the manner in which they are

grouped together to form the various tissues of the body forms an important branch of anatomy, which is termed **histology**.

The structure of the human body may be studied in two different ways. The several parts may be considered with reference to their relative positions, either as they are met with in the course of an ordinary dissection, or as they are seen on the surface of a section through the body. This is the *topographical method.* On the other hand, the several systems of organs may be treated separately and in sequence. This constitutes the *systematic method,* and it is the plan which is adhered to in this treatise.

Descriptive Terms.—Anatomy is a descriptive science founded on observation, and in order that precision and accuracy may be attained it is absolutely necessary that we should be provided with a series of well-defined descriptive terms. It must be clearly understood that all descriptions are framed on the supposition that the body is in the erect position, with the arms by the side and the hands held so that

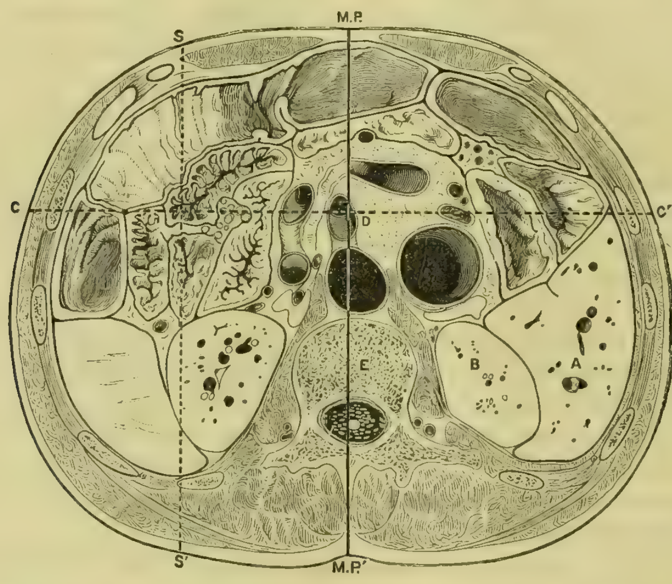


Fig. 1.—Horizontal Section through the Trunk at the Level of the First Lumbar Vertebra.

the palms look forwards and the thumbs outwards. An imaginary plane of section, passing longitudinally through the body so as to divide it accurately into a right and left half, is called the **mesial plane**, Fig. 1 (M.P.). When the right and left halves of the body are studied it will be found that both are to a large extent formed of similar parts. The right and left limbs are alike; the right and left halves of the brain are the same; there are a right and left kidney and a right and left lung, and so on. So far, the organs are said to be **symmetrically** arranged. But still a large amount of **asymmetry** may be observed. Thus the chief bulk of the liver lies to the right side of the mesial plane, and the spleen is an organ which belongs wholly to the left half of the body. Indeed it is well to state that perfect symmetry never does exist. There always will be, and always must be, a certain want of balance between symmetrically placed parts of the body. Thus the right upper limb is, as a rule, constructed upon a heavier and more massive plan than the left, and even in those organs where the symmetry appears most perfect, as for instance the brain and spinal cord, it only requires a closer study to reveal many points of difference between the right and left halves. The line on the front of the body along which the mesial plane reaches the surface is

termed the **anterior median line**; whilst the corresponding line behind is called the **posterior median line.** It is convenient to employ other terms to indicate other imaginary planes of section through the body. The term **sagittal** is therefore used to denote any plane which cuts through the body along a path which is parallel to the mesial plane (S S′); and the term **coronal** or **frontal** is given to any vertical plane which passes through the body in a path which cuts the mesial plane at right angles (C C′). The term **horizontal** as applied to a plane of section requires no explanation. Any structure which lies nearer to the mesial plane than another is said to be **internal** or **mesial** to it; and any structure placed further from the mesial plane than another is said to lie **external** or **lateral** to it. Thus in Fig. 1, A is external to B; whilst B is internal to A.

The terms **anterior** and **ventral** are synonymous, and are used to indicate a structure (D) which lies nearer to the front or ventral surface of the body than another structure (E) which is placed nearer to the back or dorsal surface of the body, and which is thus said to be **posterior** or **dorsal.** In some respects it would be well to discard the terms "anterior" and "posterior" in favour of "ventral" and "dorsal," seeing that the former are only applicable to man in the erect attitude, and cannot be applied to an animal in the prone or quadrupedal position. They have, however, become so deeply ingrained into the descriptive language of the human anatomist that it would hardly be advisable at the present moment to adopt this course. A similar objection may be raised to the terms **superior** and **inferior**, which are employed to indicate the relative levels at which two structures lie with reference to the upper and lower ends of the body. The equivalent terms of **cephalic** and **preaxial** are therefore frequently used in place of "superior," and **caudal** and **postaxial** in place of "inferior."

The terms **proximal** and **distal** should only be applied in the description of the limbs. They denote relative nearness to or distance from the trunk. Thus the hand is distal to the forearm, whilst the upper arm or brachium is proximal to the forearm.

GENERAL EMBRYOLOGY.

By Alfred H. Young and Arthur Robinson.

Although the tissues and organs of the body when fully formed differ greatly not only in respect of their functional characteristics but also with regard to their structural features, they are developed from cell elements which, at first, cannot be distinguished from one another, and all of which are the offspring of parent cells—the female cell or **ovum**, and the male cell or **spermatozoon**. Developmental processes take place in the female cell alone, but they cannot occur unless the essential elements of a sperm or male cell previously unite with it.

Like all animal cells, the ovum is a mass of protoplasm (*cytoplasm*) containing a nucleus. In many cells the cytoplasm or cell body is itself enclosed by an external investing membrane, the cell wall, and probably there is such a membrane in the ovum. Speaking generally, animal cells are minute structures, those of the human body rarely attaining a diameter of more than about ·083 mm., but they vary somewhat in size, they assume different forms, and they acquire characteristic peculiarities associated with their positions and functions; thus, whilst the majority of the constituent cells of an individual form the various tissues and organs of the body, others become reproductive or germinal cells.

Ova are simply specialised cells modified and adapted for the purpose of reproduction and the continuance of the species. They are developed in the ovary, one of the female generative organs, in the cell-lined spaces known as Graafian follicles.

When an ovum has reached a certain stage of development it is discharged from the ovary, and passing along the oviduct or Fallopian tube it eventually reaches the cavity of the uterus. Though mature and capable of being fertilised it may not be impregnated, in which case it does not remain in the uterus but is cast out from that organ. If, however, it becomes fertilised by union with the male germinal element it is retained in the uterus, and develops into an embryo which possesses all the characteristic features of the species to which it belongs and most of the special peculiarities of its parents.

When the embryo, or the fœtus as it is termed after it has assumed definite form, is capable of independent existence, its intrauterine life terminates, and it is separated from the rest of the ovum and is born. The development of the individual, however, is not complete, nor does it become complete until the new being reaches the adult condition.

The term embryology is sometimes used to include the consideration of all the developmental changes and processes which take place in the ovum from the beginning up to the final adult stage. It is more convenient, however, to restrict its application to the study of those changes which take place during the development and growth of the organism before the fœtus is separated from the ovum, or, in other words, during its intrauterine existence.

Briefly epitomised, the sequence of changes is as follows. Impregnation of the primitive nucleated ovum is followed by segmentation or cleavage. By a series of successive divisions the egg-cell is divided into two, four, eight, and ultimately into a large number of cells, and so is transformed into a multicellular mass, the morula,

The majority of the "segmentation masses" or cells, blastomeres, as they are termed, are differentiated into tissue elements, but a certain number retain the characters of the original germ-cells and become ova or sperm-cells, which form the "points of departure" of succeeding generations. Every germ-cell is derived, therefore, "by a continuous and unbroken series of cell divisions" which have extended through the past, from the most primitive ancestor, and it forms a point from which, under ordinary circumstances, all future generations will commence. It is in this sense that the changes through which a living being passes in the course of its life "may, in their completest form, be considered as constituting a morphological cycle, beginning with the ovum and ending with the ovum again."

To follow these changes it is necessary that the characters and capabilities of the constructive elements should be clearly understood. The animal cell, which plays an all-important part in the life-history of the individual, and the modified germ-cells must be carefully studied, and as far as possible the exact nature of their constituent parts ascertained.

The phenomena of impregnation and segmentation, and the subsequent developmental processes and morphological changes which result in the formation of the embryo, and, finally, the arrangements for the nutrition and protection of the ovum during its intrauterine existence, will then be considered.

THE ANIMAL CELL.

Cells are the structural units of the body. Each cell has an individual life-history within the tissue or organ to which it belongs, it is produced by a pre-existing cell, it develops and grows, is modified by circumstances, reproduces other cells similar to itself, and dies.

A cell possesses a body and a nucleus. An external investing membrane or cell wall may or may not be differentiated.

Fig. 2.—Diagram of an Animal Cell.

The **cell body** consists of protoplasm—an unstable, highly complex organic substance, the constitution of which is approximately represented by the formula $C_{60}H_{100}N_{16}O_{20}$. It is colourless, semi-fluid, viscous, insoluble in water, capable of osmosis, and it is contractile and irritable. In the living condition it always contains a certain amount of water and various inorganic matters. It is to be observed, however, that there are many varieties of protoplasm, differing somewhat in nature and qualities.

The protoplasm of the cell body is called **cytoplasm.** Under low powers of the microscope it is homogeneous or slightly granular, but with higher magnification, and especially after the application of staining agents, it is possible to distinguish—

(1) A highly refractile, elastic, and extensile network—the **cyto-reticulum** or **spongioplasm**—the meshes of which are filled with

(2) A clear, semi-fluid substance—the **cytolymph** or **hyaloplasm.**

The fibres of the reticulum present some few minute rounded bodies of doubtful nature, which are termed **microsomes.**

The **nucleus** is a spherical vesicle embedded in the cell body. It is surrounded by a distinct nuclear membrane, and usually contains nucleoli.

It consists of modified protoplasm, which is termed **karyoplasm,** the precise relation of which to the cytoplasm is not clear. Structurally it resembles cytoplasm in that it presents a fine reticulum, the fibres of which seem to be continuous with the cyto-reticulum through the nuclear membrane, whilst its meshes are occupied by **nuclear juice.**

The reticulum forms a fine network composed of **linin** fibres (achromatic

substance). There is also a coarser network, more readily stainable, consisting of **chromatin,** granular portions of which may also be embedded in the linin. Instead of forming a coarse network the chromatin may be arranged in the form of a convoluted cord, or as a number of separate filaments, and in certain cases it constitutes a series of loops from which secondary branches are projected, the apices of the loops being grouped together at one pole of the nucleus round a clear area known as the "polar field."

The **nuclear membrane** consists of both chromatin and linin.

Nucleoli are of two kinds, true and false. A true nucleolus is a small, refractile particle, of spherical outline, embedded in the reticulum. It stains deeply, and is said to consist of a special modification of the karyoplasm which is called pyrenin. False nucleoli are simply the nodes of the chromatin reticulum.

The nucleus is capable of motion; it has been seen to alter its shape in the living cell, and it undoubtedly plays an active part in the process of cell reproduction.

In addition to the nucleus many cells contain one or more small rounded bodies called **centrosomes.** Possibly they are only condensed portions of the cytoreticulum. They lie within a clear space which is known as an **attraction sphere,** from which numerous fine lines radiate.

Centrosomes become very evident when reproduction commences, but are not so distinct at other times.

The attraction sphere also becomes more evident when cell-division commences, and the contained centrosome as well as the radii which project from it appear to play important parts in the reproductive process.

Reproduction of Cells.—Cell division or reproduction may take place either—

1. By direct division—**amitosis**;
2. By indirect division—**mitosis** or **karyokinesis.**

In the **amitotic or direct form of division** the nucleus, and then the cell body, are equatorially constricted, the constrictions deepen until both are completely divided, and so two daughter cells are produced. Apparently the attraction sphere and centrosome play some part in this process, but whether their influence is initiative or directive is unknown.

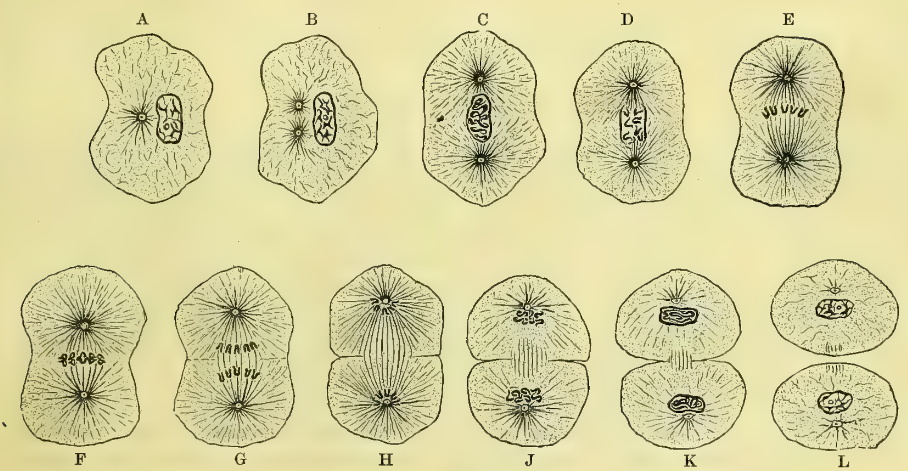


FIG. 3.—CELL DIVISION.

Successive stages of mitosis or karyokinesis (diagrammatic, modified from Henneguy). A, B, C, D, and E illustrate the phenomena of the prophase; F those of the metaphase; G and H those of the anaphase; J, K, and L those of the telophase.

Mitosis, the process of indirect division, is by far the most common mode of cell-division. It is a complex process, and the phenomena observable during its progress are classified into four groups: (1) the *prophase,* (2) the *metaphase,* (3) the *anaphase,* and (4) the *telophase.*

The phenomena of the *prophase* commence with the division of the centrosome and attraction sphere into two parts which travel to opposite poles of the nucleus. At the same time the reticulum of the nucleus disappears, and in its place a convoluted cord of chromatin, the skein or spirem, is formed (Fig. 3, A, B, and C); this is afterwards broken up into a number of segments which may be mere rods, but which more frequently have the form of V-shaped loops (Fig. 3, D). The nucleoli disappear, and some of the filaments which radiate from the newly-formed attraction spheres seem to penetrate the nuclear membrane at the poles of the nucleus. The nuclear membrane subsequently disappears, and the filaments passing from the attraction spheres into the nucleus form two cones, the bases of which meet at the equator of the nucleus, where they fuse together, forming an achromatic spindle which extends between the two attraction spheres (Fig. 3, E).

The loops, or rods, of chromatin are gradually grouped at the equator of the spindle, each rod, or chromosome, being apparently connected with one of the achromatic fibrils; and the prophase is completed.

In the *metaphase* each chromosome is split into two halves—daughter chromosomes—which separate from one another; the separation commences at the apex of each V-shaped chromosome, which appears to be attached to an achromatic fibril (Fig. 3, F).

In the *anaphase* the daughter chromosomes pass to the opposite poles of the spindle. It is suggested that this is brought about by the contraction of the spindle fibrils, but this is doubtful, and it is noteworthy that in some cases fine achromatic fibrils connecting the separated daughter chromosomes are present (Fig. 3, G and H). Slightly before, or simultaneously with, the completion of the anaphase the cell body is equatorially constricted.

During the *telophase* the constriction deepens and the cell is divided into two daughter cells. Whilst this division is taking place the daughter chromosomes, which are grouped in the neighbourhood of each attraction sphere at opposite ends of the spindle, unite into a convoluted cord, round which a nuclear membrane is formed, whilst the cord is converted into a reticulum, and nucleoli appear (Fig. 3, J, K, L). Therefore when the separation of the daughter cells is completed, at the end of the telophase, each possesses all the characteristic features of the mother cell.

Reproductive Cells.—The germinal elements, the union of which is essential to the formation of a new being, are the ovum or female element, and the spermatozoon or male element.

THE OVUM.

Structurally an ovum presents all the characteristic features of a typical cell. It is peculiar because of the large size of the nucleus and nucleolus and in the possession of two investing membranes, an inner one, the vitelline membrane, which corresponds to the cell wall, and an outer one, the oolemma or zona pellucida. Moreover, the nucleus always occupies an excentric position in the cytoplasm, and the cell body contains nutritive material in the form of yolk granules.

The constituent parts of an ovum have received distinctive names, however; thus the cell body is known as the yolk or vitellus, the nucleus is termed the germinal vesicle, and the true nucleolus is called the germinal spot.

Vitellus or Yolk.—The body of the ovum, consisting as in an ordinary cell of cytoplasm resolvable into reticulum and sap, contains also numerous granules of small but varying size called yolk granules. These are highly refractile, fatty, and albuminoid bodies containing phosphorus and mineral salts; collectively they constitute the **deutoplasm** or **nutritive yolk**, in contradistinction to the **cytoplasm** or **formative yolk.**

Nutritive or food yolk plays an important part in development. In some animals it is the only means of support for the embryo whilst in the ovum; in most mammals, on the other hand, the embryo is supplied almost from the first with food not from the egg itself, but directly from the mother through the placenta. The amount of deutoplasm present in the ova of different animals therefore varies greatly.

Ova in which there is no deutoplasm are spoken of as *alecithal.* Such ova, if they exist, are very rare; most of those usually classed under this head undoubtedly contain a certain amount of deutoplasm granules scattered throughout the cytoplasm, and are better described by the term *oligolecithal.* The size of an ovum is determined by the amount of food yolk present, and all oligolecithal ova are small; the human ovum, which may be taken as a type of the class, is about ·2 mm., or $\frac{1}{125}$th of an inch in diameter.

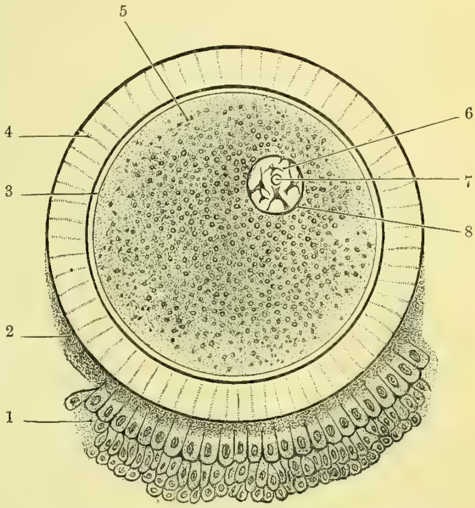


Fig. 4.—The Ovum and its Coverings (Diagrammatic).

The corona radiata, which completely surrounds the ovum, is only represented in the lower part of the figure.

1. Corona radiata.
2. Granular layer.
3. Vitelline membrane.
4. Zona pellucida (oolemma).
5. Vitellus or Yolk.
6. Germinal vesicle (nucleus).
7. Germinal spot (nucleolus).
8. Nuclear membrane.

As the deutoplasm is increased in amount the ovum is increased in size. The deutoplasm also tends to accumulate in certain situations; if the accumulation is at one extremity of the cell the ovum is described as *telolecithal;* such ova are naturally divisible into two areas or poles, a cytoplasmic or formative pole, and a deutoplasmic or nutritive pole.

In *eutelolecithal* ova the deutoplasm almost entirely displaces the cytoplasm from one pole, as in the egg of the fowl, in which the cytoplasm is represented by a disc spread over one pole of a large deutoplasmic mass. In many of the arthropoda the deutoplasm accumulates at the centre of the ovum, which is therefore termed *centrolecithal.*

The **germinal vesicle** or nucleus of the human ovum is about ·05 mm. or $\frac{1}{500}$th of an inch in diameter, *i.e.* $\frac{1}{4}$ the size of the whole ovum. It lies excentrically in the yolk, and has the usual characters of a cell nucleus, *i.e.* it possesses a nuclear membrane within which is the karyoplasm, divisible into reticulum or nucleoplasm, and nuclear juice. The nucleoplasm consists of chromatin and achromatic fibres (linin), and the nuclear juice contains one or more spherical and highly refractile true nucleoli or germinal spots; the nodes of the reticulum constitute false nucleoli.

In addition to the nucleus, the vitellus, at certain periods, also contains a structure known as the **vitelline body** or **body of Balbiani.** This body is a spherical structure which appears when the primordial ova cease to multiply and begin to increase in size. Apparently it is derived from the nucleus, and it consists of a central nodule surrounded by a zone of modified protoplasm. It disappears long before the ovum becomes mature, and it probably represents an ancestral organ corresponding with a portion of the macronucleus of the infusorian ovum.

The Vitelline Membrane.—The vitelline membrane is simply the peripheral portion of the vitellus, modified and transformed into a fine structureless envelope which covers the outer surface of the yolk. It is usually closely applied to the inner aspect of the outer membrane, the zona pellucida, and is best seen in the dead ovum and after treatment by reagents. It is therefore thought by some to be merely a condensation of the outer part of the vitellus produced by the action of the reagents. There is evidence, however, to show that it is present in the normal living ovum.

The Zona Pellucida or Oolemma.—This membrane is thick, tough, and refractile. It serves as a protective covering for the ovum, and persists for a considerable time after its fertilisation, only disappearing when the ovum becomes attached to the uterus. It is perforated by numerous fine canals, which give to the broad clear membrane a finely striated appearance, from which circumstance it has been called the "zona striata." The zona pellucida is not formed by the ovum, but is secreted by the cells of the Graafian follicle in which the ovum lies; it is consequently

regarded as a secondary membrane, and is altogether different from the vitelline membrane. The perforations in the zona serve for the passage of nutritive material to the ovum; they also allow the spermatozoon to reach the ovicell.

When the ovum leaves the Graafian follicle it is surrounded by several layers of cells, the innermost of which are columnar. They are derived from the cells of the follicle, and collectively constitute the **corona radiata**; the cells gradually diminish in size, and ultimately disappear. Their function is unknown, but between them and the zona pellucida there is a layer of granular matter, probably formed by the cells of the corona radiata, which rapidly swells up when the ovum is liberated from the follicle, and forms a gelatinous elastic layer called **the albumen**; this increases in thickness as the ovum passes along the oviduct, and persists for some time after it enters the uterine cavity. The function of the albumen has not been definitely ascertained; it may act merely as a protective covering against undue pressure, possibly it may be nutritive, whilst in the dog it apparently helps to fix the ovum to the wall of the uterus. It has not been found in all mammalian ova, and it has not been seen round the human ovum; still it may be present, for human ova at the stage when it might be expected to develop have not yet been observed.

Special Characters of the Ovum.—Though the ovum, as compared with an ordinary animal cell, presents no obvious structural modifications, it undoubtedly differs greatly in its capabilities and life-history. Unlike an ordinary cell it has no inherent power of division into **equal** parts, and it cannot divide in the usual manner until it has been fertilised by union with the male element; but before fertilisation occurs the ovum twice undergoes an **unequal** division during the period of ripening or maturation.

Maturation of the Ovum.—Whilst in the ovary the ovum, at first small,

FIG. 5.—THE MATURATION OF THE OVUM: EXTRUSION OF THE "POLAR BODIES" (Diagrammatic).

A, An ovum at the commencement of the process; B, After the formation of the spindle. The chromosomes are gathered at the equator of the spindle in groups of four, *i.e.* in "tetrads," each of which consists of two "dyads." C, One apex of the spindle has projected into a bud on the surface, and the dyads have passed to the poles; D, The separation of the first polar body; E, The commencement of the second polar body; F, The completion of the second polar body.

gradually increases in size. Before, or immediately after, its discharge from the Graafian follicle it matures in preparation for fertilisation.

The phenomena observable during the period of maturation are essentially

similar to those met with in the mitotic or karyokinetic division of cells. The excentrically situated nucleus (germinal vesicle) moves to one pole of the ovum, the nuclear membrane and the nucleoli disappear, and an achromatic spindle is formed, but, so far as the mammalian ovum is concerned, there is no evidence either of centrosomes or attraction spheres at the poles of the spindle; possibly they are present, but they are not visible under the conditions in which the ova can be observed.

At first the spindle lies horizontally, but gradually it turns till its long axis is perpendicular to the surface of the ovum; then one pole of the spindle is protruded, carrying with it a small mass of the cytoplasm and forming a bud.

Simultaneously half the chromosomes present in the nucleus disappear, and the remaining half accumulate at the equator of the spindle in the form of rods. Each rod divides into four parts and thus becomes a "tetrad" (end of prophase). Each tetrad then separates into two "dyads" (metaphase). In the next stage (anaphase) the dyads diverge, one half passing to the outer pole of the spindle which projects into the bud, the other half passing to the inner pole. The bud with its dyads then separates, forming the **first polar body**. Thus both the first polar body and the remainder of the ovum, at the end of the unequal division which has taken place, possess the same number of chromatin particles (chromosomes) as the original ovum.

The second unequal division of the ovum commences directly on the termination of the first, and results in the formation of a **second polar body**. The achromatic spindle is reformed and the remaining dyads are grouped at its equator. The outer extremity of the spindle projects into a second bud, whilst the two halves of each dyad diverge and pass to opposite poles of the spindle. Those which group themselves at the outer pole separate with the bud, and the second polar body is completed.

The half-dyads at the inner pole of the spindle travel towards the centre of the ovum, and form the chromatin reticulum of a new nucleus in the cytoplasm of the ovum, which is known as the **female pronucleus**.

Therefore the mature and the immature ova differ from each other chiefly in that the former contains only half the number of chromosomes present in the latter.

THE SPERMATOZOON.

Spermatozoa are modified cells produced in the testicles or male generative glands. They are formed by a division of the **spermatogonia** or **sperm-mother cells**, which correspond with primitive ova. The daughter cells of the spermatogonia are called **spermatocysts**, and the grand-daughter cells **spermatids**. By various processes, during which they fuse with special basal, sustentacular, or nurse cells, the spermatids are converted into spermatozoa, which probably, though this has not yet been proved in mammals, contain half the number of chromosomes which were present in the sperm-mother cells. There is no doubt that the mature ova and the spermatozoa, so far as their development and chromatin particles are concerned, are very similar. Each is formed from a primary germinal cell, that is, from the primitive ovum and sperm-mother cell respectively. Each of these undergoes division and the daughter cells produced, that is, the functional ovum and the first polar body in the former case, and spermatocysts in the latter, contain a number of chromosomes identical with that originally present in the mother cell. By a second division, which follows immediately on the first, the daughter cells, with the exception perhaps of the first polar body, are transformed into grand-daughter cells. These are therefore represented by the second polar body and the mature ovum in the case of the female, and by the spermatids, which ultimately become spermatozoa, in the male. Each grand-daughter cell contains only half the number of chromosomes which are originally present in the mother cell. But the cells derived from the primitive ovum differ from the descendants of the sperm-mother cell in that only one, the mature or functional ovum, appears to be capable of further development, whilst the four spermatozoa are apparently of equal value.

It is both interesting and significant that in some cases the first polar body divides simultaneously with the separation of the second polar body, each of its segments containing the same number of chromosomes as the female pronucleus. This condition, indeed, is by no means uncommon amongst invertebrates. It occurs in *Ascaris*, in certain crustaceans, and in some molluscs. Amongst vertebrates, however, the division of the first polar body, so far at least as present observations go, must be regarded as exceptional. It has been seen to occur in bats by Van Beneden and Julin, and in mice by Tafani and Sobatta, but apparently even in these it is not a constant phenomenon. As regards the spermatozoa also, though it is known that they are formed by the division of sperm-mother cells, the exact details of their development in mammals have not yet been satisfactorily elucidated. It seems, however, very probable that in the higher forms of animal life, as in the lower, the processes of maturation of the ovum and the formation of the spermatozoa are simply those of cell-division associated with a reduction of the number of chromosomes in the resulting grand-daughter cells; these latter being represented in the higher forms, including mammals, on the male side by the spermatozoa, and on the female side by the second polar body and the mature ovum, except in the apparently occasional instances in which the first polar body divides, and in this case there are three polar bodies and the mature ovum.

A **spermatozoon,** like the ovum, is a nucleated mass of cytoplasm, but it presents striking modifications in structure. It is very small, and possesses a head, a neck, a body, a tail, an end-piece, a spear, an axial filament, a spiral filament, a spiral membrane, a head-cap, and a certain amount of protoplasmic substance called the protoplasmic remnant. The more obvious of these, namely the head, body, long filamentous tail, and thin end-piece, have long been recognised as essential elements of a spermatozoon (Fig. 6), and it is only comparatively recently that the remaining parts have been specially described. The **head** is ovoid, and laterally compressed, so that when viewed from the side it appears pointed; it is about 4·5 μ long, 2·5 μ broad, and 1·5 μ thick. It consists of two parts—an anterior clear, and a posterior more stainable and transversely striated. Within the head is a central body which is clear, refractile, and not easily stainable; in stained specimens it is sometimes marked by coloured lines, and occasionally it is divided into several pieces. The head is traversed by the axial filament, and it is surrounded by the clear **head-cap,** within which is a thin protoplasmic layer; this is continuous posteriorly with the **protoplasmic remnant** which surrounds the neck.

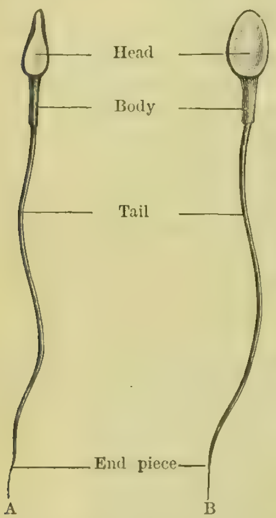


Fig. 6.—Human Spermatozoa (after Retzius).

A, Side view; B, Front view.

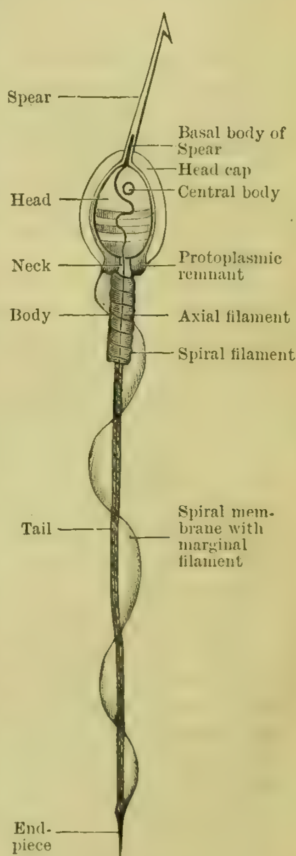


Fig. 7.—Structure of a Spermatozoon (Diagrammatic).

The **neck** is a very short constricted portion uniting the head and body. It is clear, it is traversed by the axial filament, it sometimes contains a rounded body, the **globuloid body,** and it is surrounded by the protoplasmic remnant, which latter varies considerably in amount.

The **body** is somewhat longer than the head, it also is traversed by the axial filament, it is encircled by the spiral filament, and it gives attachment to the spiral membrane.

The **tail** or **flagellum** is about six times the length of the body, it may terminate in an enlargement or it may taper towards its extremity, the axial filament lies in its centre, and the spiral filament and spiral membrane are coiled around it. Projecting from its posterior end is a fine filamentous process, the **end-piece,** which

appears to be the backward prolongation of the axial filament; it is occasionally cleft into several fibrils.

The **spiral** and **axial filaments** consist of numerous darkly-staining fibrils. The former is coiled round the body and tail. The latter is continuous posteriorly with the end-piece, and it is continued forwards through the tail, body, and neck. In some animals it is said to end anteriorly in a globuloid body at the base of the head, but in the human spermatozoon it can be traced through the head to the "spear" (Von Bardeleben).

The **spear** projects obliquely forwards from the apex of the head. It is a unibarbed process, about twice as long as the head, and may be bent or curved upon itself. It contains an elongated body at its base, and it appears to be continuous posteriorly with the axial filament.

The **spiral membrane** is an extremely fine membrane which is attached to the body and tail. Its free margin is strengthened by a marginal filament.

Spermatozoa move freely in fluid media, and each rotates upon its axis by means of the spiral membrane as it is propelled forwards by the lashing and contractile movements of the tail.

The morphological value of the various parts of the spermatozoon is not yet definitely determined, but it is generally considered that the head represents a cell nucleus. The axial and spiral filaments are believed to consist of chromatin, and therefore they also are probably nuclear constituents. The protoplasmic remnant probably consists of cytoplasm, and the head-cap is apparently a remnant of the attraction sphere of the spermatid from which the spermatozoon was developed. Many observers have recognised the centrosome as a small structure in the body of the spermatozoon—possibly the globuloid body—but Nissing's more recent observations upon mammalian spermatozoa have convinced him that the centrosome takes part in the formation of the spike; it is possibly represented therefore by the elongated body which Bardeleben has seen in the base of the spear of the human spermatozoon.

FERTILISATION OF THE OVUM AND THE RESULTS THAT ENSUE.

Fertilisation.—The mature ovum is fertilised by a spermatozoon. The two generative elements meet, and fertilisation takes place as a rule in the upper part of the Fallopian tube. The spear of the spermatozoon penetrates the zona pellucida of the ovum, boring through it with a rotatory motion produced by the spiral membrane. At the same time a conical projection, the **cone of attraction,** appears on the surface of the ovum, within the zona pellucida, directly beneath the point at which the spermatozoon is entering. The head, and probably a portion of the body of the spermatozoon, plunge into the cone of attraction; the remainder of the body and the tail are cast off and disappear. The portion of the spermatozoon which enters the cytoplasm of the ovum is converted into a nucleus, the **male pronucleus,** which is accompanied by its attraction sphere and centrosome. When the male pronucleus is distinctly formed the granules of the cytoplasm in its neighbourhood begin to radiate around it, as if under its influence, and the pronucleus itself travels inwards.

As the male pronucleus approaches the female pronucleus the latter shows signs of activity, it undergoes changes of form, and moves to meet the male pronucleus. For a time the two pronuclei lie in juxtaposition, and ultimately they fuse together, forming the **first segmentation nucleus.**

The first segmentation nucleus is accompanied by two centrosomes which lie at its opposite poles; they are the products of the male centrosome which divides as the pronuclei fuse. The fertilised ovum, the product of the fusion of the mature ovum and the spermatozoon, contains in its nucleus, the first segmentation nucleus, the same number of chromosomes as the primitive ovum or the sperm-mother cell, but the chromosomes of the segmentation nucleus are derived partly from a male and partly from a female individual.

According to some authorities, both the male and female pronuclei are accompanied by centrosomes, and at the moment of union of the pronuclei each centrosome divides; thus four

half-centrosomes are formed, two male and two female. From the four half-centrosomes two new centrosomes are formed by the union of half a male centrosome with half a female centrosome. Each of the two centrosomes, therefore, which accompany the first segmentation nucleus contains both male and female elements.

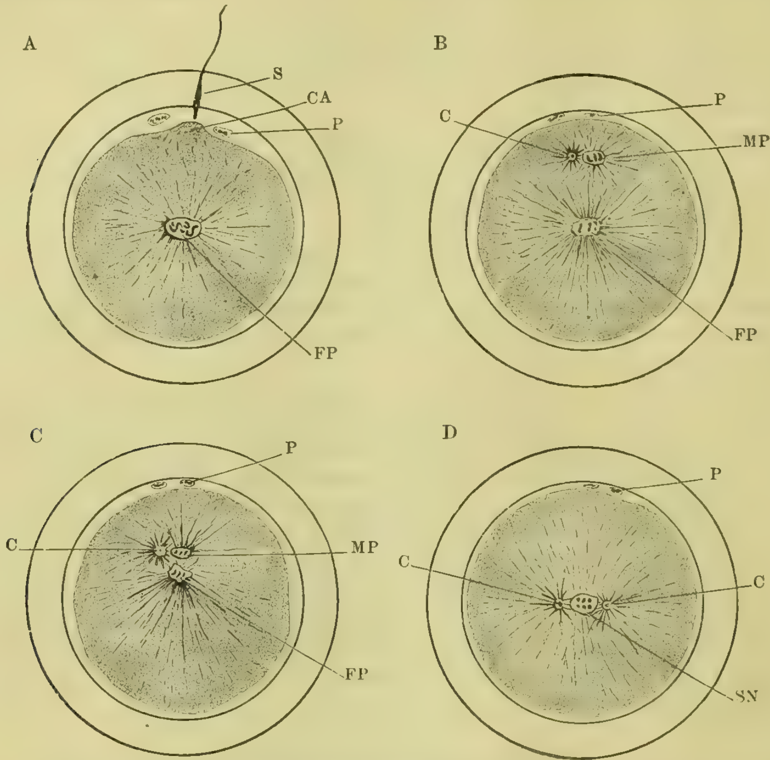


FIG. 8.—FERTILISATION OF THE OVUM (Diagrammatic).

A, The entrance of the spermatozoon and the formation of the cone of attraction ; B, The appearance of the centrosome ; C, The approachment of the male and female pronuclei ; D, The first segmentation nucleus.

C. Centrosome. FP. Female pronucleus. P. Polar body.
CA. Cone of attraction. MP. Male pronucleus. SN. Segmentation nucleus.

Segmentation.—Segmentation is the division of the fertilised ovum (oosperm) into a number of cells. These cells are afterwards arranged in layers—the germinal layers or layers of the blastoderm ; ultimately they are differentiated into the tissue elements of the body.

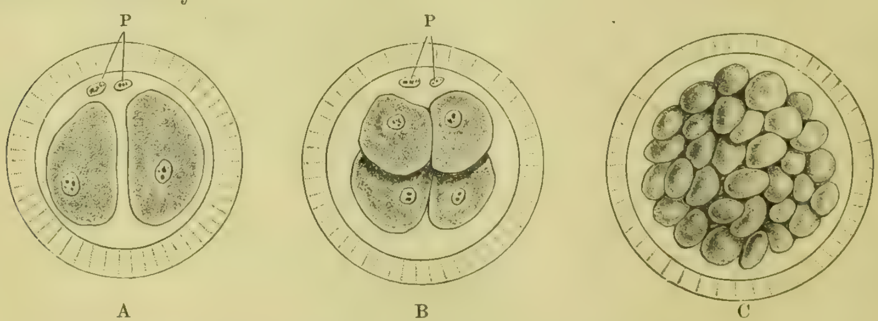


FIG. 9.—SEGMENTATION OF THE FERTILISED OVUM IN THE RABBIT.

Formation of blastomeres and morula (Diagrammatic).
A, Division into two segments ; B, Division into four segments ; C, Morula.
P, Polar bodies.

The phenomena of segmentation have not been observed in the human ovum, and it is to be understood that the following description is based chiefly upon the conditions met with in rodents, more especially in the rabbit, an animal well adapted for the study of these phenomena.

After a period of quiescence, which succeeds the fusion of the male and female pronuclei, a period of activity supervenes, during which repeated divisions of the impregnated ovum result in the production of a solid mass of cells called a **morula.** The divisions are mitotic, and all the phenomena associated with mitosis are readily observable in properly prepared specimens.

The planes which separate the several segments of the divided ovum in its various stages are termed the "planes of segmentation," and in some animals, possibly in all, the first plane by which the ovum is divided into the first two daughter cells coincides with the line along which the pronuclei passed to their fusion; it indicates the future mid-axial or mesial plane of the body, the descendants of the cell lying to the right of it being developed into the right half of the body, and those of the cell to the left into the left half. There is no proof, however, that this occurs in mammals; all that is definitely known is that the first division separates the ovum into two parts of unequal size but of similar colour and structure.

The second plane of segmentation is at right angles to the first and it separates the two daughter cells into four grand-daughter cells, of which, in some cases, two may be larger and two smaller. The subsequent divisions occur irregularly, and they result in the formation of numerous cells (blastomeres) which apparently only differ in size in the rabbit, but which also differ in appearance in many mammals. They are mixed together so irregularly that it is impossible to distinguish the descendants of one daughter cell from those of the other, and in this, the **morula stage,** there is frequently no indication of any separation of the cells into layers. In the meantime the polar bodies have disappeared.

The next phenomenon of importance is the appearance of a cavity—**the segmentation cavity**—in the morula; the ovum assumes a vesicular character, and is now termed a **blastula.** Simultaneously with the appearance of the cavity the cells of the morula are arranged in two groups—an outer and an inner. The cells of the outer group form a layer, the primitive **ectoderm** or **epiblast**; those of the inner group remain massed together and constitute the **inner cell mass.** The two groups are in contact at one pole of the ovum, and it is in this region that the embryo develops. Though at first the inner cell mass is not laminar, it soon becomes so by the migration and flattening of its cells; the inner layer thus formed is termed the **entoderm** or **hypoblast.**

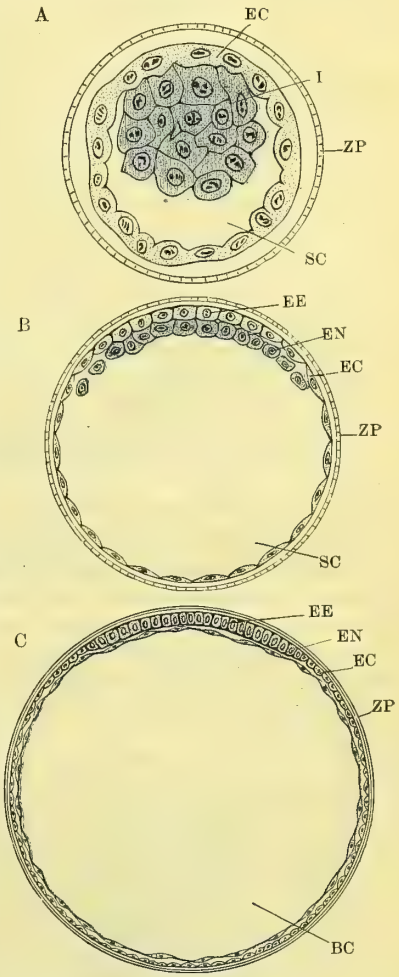


Fig. 10.—Conversion of the Morula to the Blastula.

Formation of blastodermic vesicle and membrane.

A, Appearance of segmentation cavity and attachment of inner cell mass to ectoderm at upper pole of ovum; B, Extension and flattening of inner cell mass; C, Completion of bilaminar blastodermic vesicle. BC, Blastodermic cavity; EC, Ectoderm; EE, Embryonic ectoderm; EN, Entoderm; I, Inner cell mass; SC, Segmentation cavity; ZP, Zona pellucida.

The ectoderm and entoderm together constitute the blastoderm or blastodermic membrane, which is bilaminar, and the vesicle of which they form the wall is no longer spoken of as the blastula, but as the **blastodermic vesicle.**

In the rabbit the embryonic part of the ectoderm is formed from the outer cells of the inner cell mass which unite with the corresponding part of the primitive ectoderm (Rauber's layer). This, however, is merely a peculiarity found in the rabbit and some other mammals; more generally the whole of the inner mass becomes entoderm.

Structure of the Ectoderm and Entoderm.—The cells of the ectoderm are at first irregular in size and shape, and their outlines are indistinct; but after a short time the ectoderm cells at one pole of the blastodermic vesicle become cubical or slightly columnar, whilst the remaining cells of the outer layer are flattened and have irregular outlines. The columnar cells form the ectoderm of the embryo, and the flattened cells are utilised in the formation of nutritive and protective structures known as the placenta and fœtal membranes.

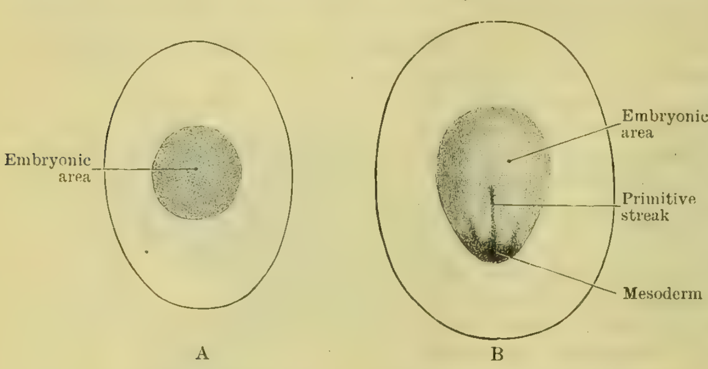


Fig. 11.—Surface View of the Blastodermic Vesicle.
Showing the embryonic area and the commencement of the mesoderm.
A, [Before the appearance of the primitive streak—the embryonic area is circular in form and bilaminar throughout; B, After the appearance of the primitive streak. The posterior end of the primitive streak shows a crescentic thickening, which indicates the commencement of the mesoderm or middle layer of the blastodermic membrane.]

The cells of the entoderm are also, at first, very irregular in shape and size, but afterwards, as they are spread out into a layer, they become more or less rounded, and they anastomose together by filamentous processes. At a still later period they are transformed into polygonal plates which appear spindle-shaped in section (Figs. 10 and 12).

The Embryonic Area.—When the upper pole of the bilaminar blastodermic vesicle is examined in surface view from above, a dark, somewhat opaque circular area is visible; this is known as the embryonic area. It is coextensive with the columnar portion of the ectoderm. Very soon after it appears the embryonic area becomes ovoid; the small end of the ovoid area is posterior, that is, it lies in the region which is afterwards converted into the posterior part of the embryo. At

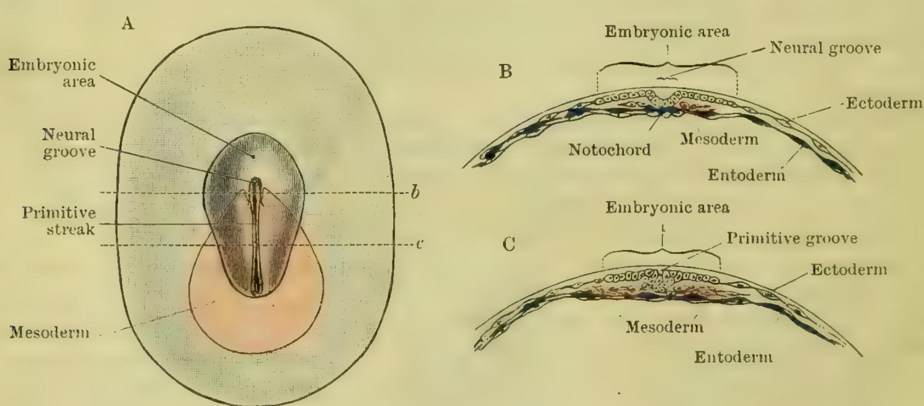


Fig. 12.—The Upper Pole of the Blastodermic Vesicle.
Showing the embryonic area, the primitive streak with the extension of the mesoderm from its sides and posterior end, and the commencement of the neural groove.
A, Surface view (diagrammatic); B and C, Transverse sections through the blastoderm of the ferret at the stage represented in A and along the lines *b* and *c* respectively.

the hinder end of the ovoid area a still darker patch of triangular form is developed; this soon becomes crescentic, and is the first indication of the primitive streak and of the formation of a third blastodermic layer termed the **mesoderm** or **mesoblast**.

The **primitive streak** consists of thickened ectoderm which is seen in transverse sections projecting downwards, and resting upon the entoderm, in the form of a ridge.

From the sides and the posterior extremity of the ectodermal ridge a lamina of

cells projects outwards, and gradually insinuates itself between the ectoderm and the entoderm over the whole area of the vesicle, except in certain regions to be afterwards described. This lamina is the rudiment of the mesoderm. With the formation of the mesoderm the blastodermic membrane becomes trilaminar.

The majority of the cells of the mesoderm are derived from those of the primitive streak, but it is said that cells from the entoderm also take part in its formation. Young mesodermal cells are round or ovoid, and some give off numerous processes. In later stages they may assume various shapes, and many closely resemble the cells of the ectoderm or those of the entoderm.

As the blastodermic vesicle grows, the embryonic or germinal area becomes pyriform and increases in length, principally in the posterior part of its extent where the primitive streak is situated; at the same time the streak lengthens and becomes more linear. For a short time a groove, the **primitive groove,** appears on the surface of the streak. It is deepest in front, where in some mammals, including man, a small transitory perforation is formed, the **neurenteric canal.**

A second broader and shallower groove then appears in the embryonic area immediately in front of the primitive streak; this is the **neural groove,** the rudiment of the nervous system. The neural groove, its bounding folds, and the nervous

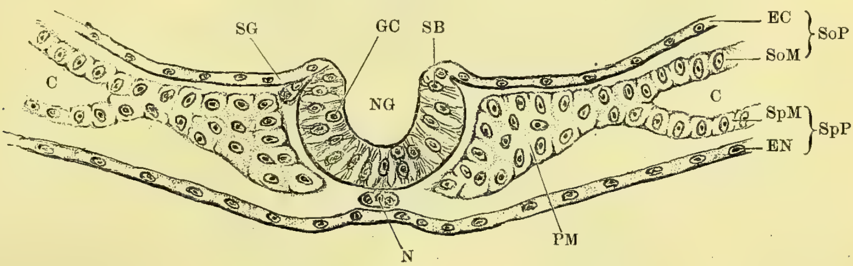


Fig. 13.—Transverse Section of a Ferret Embryo.

Showing neural groove before the separation of the paraxial from the lateral mesoderm.

C. Cœlom. GC. Germinal cell. PM. Paraxial mesoderm. SoM. Somatic mesoderm.
EC. Ectoderm. N. Notochord. SB. Spongioblast. SoP. Somatopleure.
EN. Entoderm. NG. Neural groove. SG. Spinal ganglion. SpM. Splanchnic mesoderm.
SpP. Splanchnopleure.

system subsequently developed from them are formed entirely of ectodermal elements, which at first are continuous with those forming the outer layer of the embryo. The posterior end of the neural groove embraces the anterior end of the primitive streak and groove, and at this period the neurenteric canal forms a communication between the interior of the ovum and the bottom of the neural groove, which latter afterwards becomes the closed canal of the central nervous system. In some vertebrates the neurenteric canal persists for a considerable period, and upon the development of the alimentary canal it constitutes a communicating channel between it and the cavity of the neural tube.

As the neural groove grows backwards the anterior part of the primitive streak is absorbed, and although the posterior part continues to grow, the primitive streak as a whole diminishes in length; ultimately the greater part of the primitive streak disappears, but a portion is recognisable for a considerable time extending from the base of the tail, a transitory structure in the human embryo, to the ventral wall of the body. This portion forms the posterior boundary of the primitive alimentary canal; it remains bilaminar, and is called the cloacal membrane.

The primitive streak is of great morphological importance; recent researches have shown that from it and the cells in its neighbourhood practically the whole of the body of the embryo, with the exception of the anterior part of the head and heart region, is developed. It probably represents the mouth of a remote (pre-vertebrate) ancestor, the fused lips of which formed the body of a primitive vertebrate animal. The aperture of this mouth is still represented in lower vertebrates by an opening known as the blastopore. The neurenteric canal is the only representative of the opening in the human subject.

The **neural or medullary groove** is bounded laterally by medullary folds

which are continuous in front of the groove but separate behind, where they embrace the anterior end of the primitive streak. The neural groove increases in length both in front and behind. The backward increase takes place at the expense of the primitive streak, whilst the anterior increase is due to the rapid growth of the anterior part of the embryonic area; at the same time, not because of, though coincident with, an increase of the mesoderm which has grown beneath them, the medullary folds are gradually elevated, and their apices bending inwards unite together over the neural groove, which is thus converted into a tube or canal —**the neural tube.**

Along the line of union the neural tube is connected, for a time, with the surface ectoderm by a ridge of cells, the **neural crest.** The crest soon separates

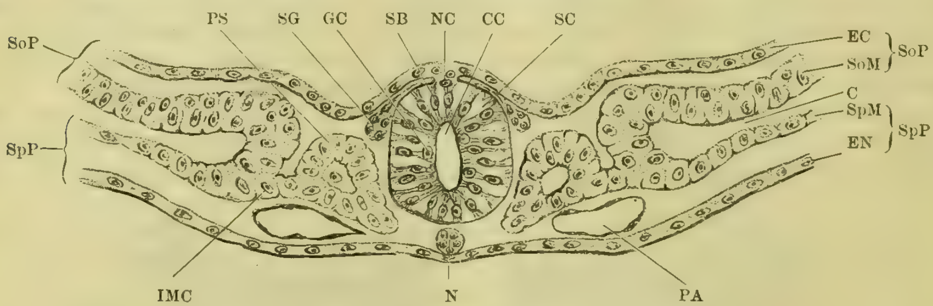


FIG. 14.—TRANSVERSE SECTION OF FERRET EMBRYO.

Showing the closure of the neural groove, the formation of the neural crest, the outgrowth of the spinal ganglia, the commencement of the separation of the paraxial mesoderm from the lateral plates, and the differentiation of the intermediate cell mass.

C. Cœlom. CC. Central canal. EC. Ectoderm. EN. Entoderm. GC. Germinal cell. IMC. Intermediate cell mass. N. Notochord. NC. Neural crest. PA. Primitive aorta. PS. Protovertebral somite. SB. Spongioblast. SC. Spinal cord. SG. Spinal ganglion. SoM. Somatic mesoderm. SoP. Somatopleure. SpM. Splanchnic mesoderm. SpP. Splanchnopleure.

from the surface, but it remains connected with the neural tube and is utilised in the formation of the cranial and spinal nerve ganglia, whilst the walls of the neural tube are converted into the nervous and sustentacular tissue elements of the whole of the central nervous system (brain and spinal cord).

Before the tube is closed the neural groove is dilated at each end (see Fig. 18). The posterior dilatation is single; it constitutes the rhomboidal sinus, which under ordinary circumstances soon disappears. Anteriorly, numerous dilatations are distinguishable at first. The exact number of these dilatations (neuromeres) is said to be eleven. As the tube closes they resolve themselves into three distinct vesicles termed the **primary cerebral vesicles.** These constitute the rudiments of the fore, mid, and hind brains, and their respective ventricular cavities. The remainder of the cavity of the tube becomes the central canal of the spinal cord.

After the separation of the neural crest from the surface, the mesoderm completely surrounds the whole of the neural tube, and from it are formed the membranes of the brain and spinal cord and their skeletal environments.

The ectodermal cells which form the wall of the primitive neural tube are ill-defined, but they soon differentiate into two sets, **spongioblasts** and **germinal cells.** The spongioblasts are the more numerous, they are columnar in form, and all extend from an internal limiting membrane which is developed round the periphery of the central canal, to an external limiting membrane which forms the outer limit of the neural tube. There is frequently considerable difficulty in recognising their columnar character, even in the early stages, partly because their nuclei do not all lie at the same level, and partly because they are so closely apposed. The spongioblasts are converted into the sustentacular tissue, or **myelospongium,** of the brain and spinal cord, but all do not undergo precisely the same transformations. The inner portions of those spongioblasts whose nuclei lie near the central canal retain a columnar form, and cilia grow from their free surfaces into the lumen of the canal; in other words, they are converted into the ciliated epithelium of the central canal,

but the outer portions of the same cells are transformed into fibrillar processes which terminate externally by fusing with the external limiting membrane. The remaining spongioblasts entirely lose their columnar form, they become much branched, and their branches interlace with the fibrillar processes of the ciliated epithelial cells, and with similar branches of neighbouring cells, forming the reticular sustentacular tissue or myelospongium; the external limiting membrane is produced by the close interweaving of the peripheral myelospongial fibrils.

The germinal cells are spherical in outline, and contain clear protoplasm and darkly-staining nuclei. They lie between the inner ends of the spongioblasts close to the central canal where, at the fourth or fifth week, they form an irregular layer, and very soon give rise to a new generation of cells, the **neuroblasts**, or young nerve-cells. Each neuroblast rapidly becomes pyriform by the outgrowth of an **axial process** or **axon**, which projects from its outer end towards the periphery of the tube.

Shortly after their formation the neuroblasts migrate outwards, and ultimately those of the cord are arranged in longer or shorter columns in the myelospongium, whilst those of the brain are grouped together in definite areas to form the cerebral nuclei.

Each neuroblast as it develops gives off many processes, which vary in length and thickness. The first formed of these is the axial process or axon already referred to. It carries impulses from the cell, gives off lateral branches, and terminates either in association with a special end-organ or by ramifying amidst other nerve-processes or round a nerve-cell of the central or peripheral nervous system. The remaining processes of the neuroblast are called **dendrites** or protoplasmic processes. They are usually shorter and more branched than the axon, and they carry impulses to the cell. The whole system of cell body, axon, and dendrites into which a neuroblast develops is termed a **neuron.**

Every neuron is a separate and distinct entity. Its processes neither anastomose together nor with the processes of other neurons. They lie, however, in close contiguity with either the body or processes of other neurons or with special end-organs, and it is possible for impulses to pass from one neuron to another although there is no structural continuity between them.

Extension of the Mesoderm, and Division of the Blastodermic Membrane into Areas.—It has already been pointed out that when the primitive streak first appears it consists of a thickened ridge of ectoderm situated in the posterior part of the embryonic area and resting upon the entoderm. The anterior end of the ridge soon fuses with the entoderm beneath it, and from its sides and posterior extremity a lamelliform outgrowth, the mesoderm, is projected between the ectoderm and entoderm. At its commencement the mesoderm is an outgrowth from the primitive streak, but during its subsequent extension it is probably added to by cells proliferated from the entoderm.

As it extends the mesoderm forms a semilunar sheet of cells, the concavity of the semilune being turned forwards, whilst the convexity is gradually projected beyond the margins of the embryonic area. The cornua of the semilunar sheet grow forwards on either side of, and at some little distance from, the middle line, immediately beneath the medullary folds. Each cornu on reaching the anterior end of the embryonic area bifurcates, and the resulting processes unite with their fellows of the opposite side.

At the same time the mesoderm grows from its convex margin, and extends over the rest of the ovum as a continuous sheet. But even when the extension is completed, in the majority of mammals, three areas on the upper aspect of the ovum remain devoid of mesoderm, and consist only of ectoderm and entoderm.

The largest of these areas lies directly in front of the embryonic region. In many mammals it is folded upwards and backwards over the head of the embryo, when this becomes distinguishable, and it takes part in the formation of one of the protecting fœtal membranes, viz. the amnion; it is therefore called the **proamnion,** and the area from which it is developed constitutes the **proamniotic area.** Probably it is not present in the human blastoderm, or if it exists it is very transitory.

The second of the areas into which the mesoderm does not extend lies in the

embryonic region. It is separated from the proamniotic area by a bar of mesoderm in which the pericardial cavity afterwards appears. The anterior part of this second area is situated in front of the neural groove, and as, at a later period, it forms a septum between the primitive mouth and the pharynx, it may be termed the **bucco-pharyngeal area.** The posterior part of the area forms the floor of the medullary groove, and as the notochord is formed from its entodermal layer we have named it the **notochordal area.**

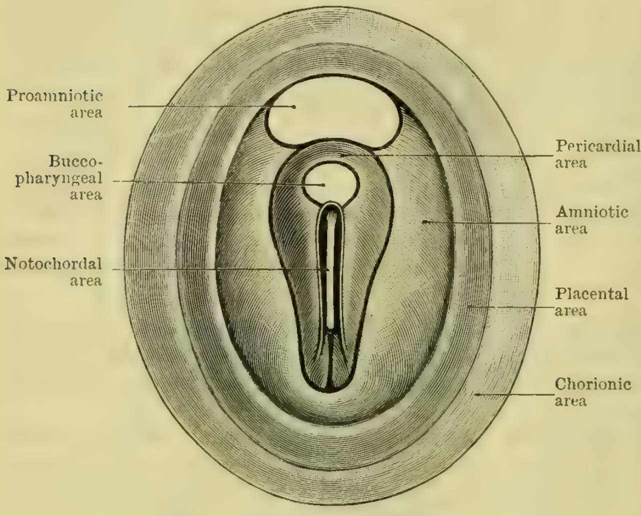


FIG. 15.—SURFACE AREAS OF THE BLASTODERM.

The third area corresponds to the posterior part of the primitive streak. It extends from the base of the tail towards the umbilicus, forming the cloacal membrane, which forms the posterior boundary of the primitive alimentary canal. It is eventually perforated by the genito-urinary and anal apertures.

Except in the areas just described, the blastodermic membrane is trilaminar, and at an early period it is possible to distinguish the regions in which the heart and pericardium, the amnion and the placental and non-placental parts of the chorion are subsequently developed. These regions form fairly well-defined areas, to the relative positions of which reference may now be made.

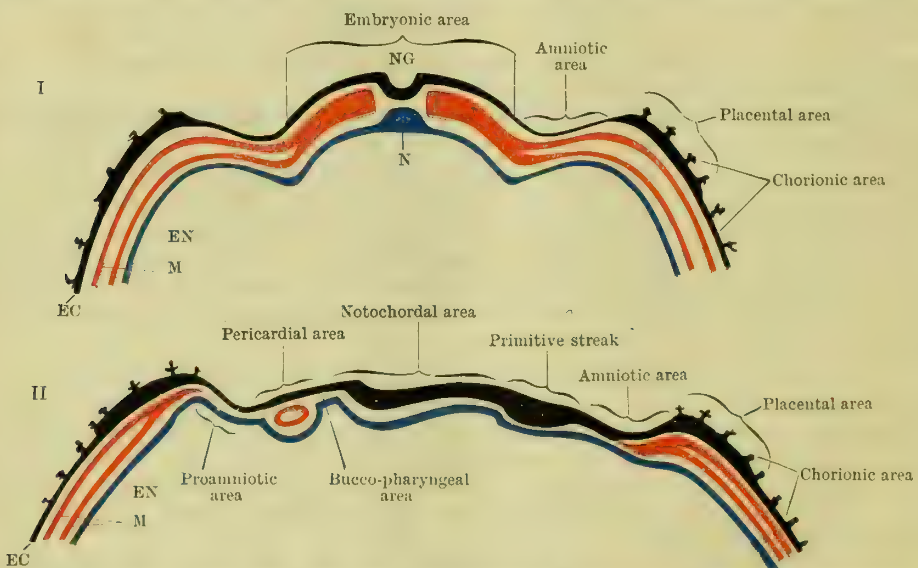


FIG. 16.—SECTIONS SHOWING THE DIFFERENT AREAS OF THE BLASTODERMIC VESICLE (Diagrammatic).
I. Transverse section ; II. Longitudinal section.
EC. Ectoderm. M. Mesoderm. N. Notochordal thickening.
EN. Entoderm. NG. Neural groove.

The anterior part of the embryonic area in front of the bucco-pharyngeal area is the region in which the pericardium and heart are developed, and it may therefore be termed the **pericardial area.**

The blastodermic membrane immediately surrounding the embryonic area,

including the proamniotic part in those animals in which it exists, is the **amniotic area,** and this is bounded externally by a band of elevated and thickened ectoderm, which indicates the **placental area.** The latter, together with the blastoderm over the rest of the ovum, forms the **chorionic area,** which is separable, therefore, into placental and non-placental portions.

These areas are further referred to in the description of the folding off of the embryo and the formation of the fœtal membranes and placenta.

Formation of the Notochord.—The notochord is the primitive skeletal axis of the embryo. When differentiated it forms a rod which intervenes between the ectodermal neural tube and the entoderm of the primitive alimentary canal. It is developed from the entoderm beneath the neural groove in the notochordal area. A linear strip of entoderm thickens and then separates as a solid rod of cells, the continuity of the entodermal layer being restored beneath it. When it is completed the notochord extends from a point immediately behind the primitive forebrain, and beneath the anterior end of the midbrain, to the anterior end of the primitive streak, and in later stages, as the skeleton is formed, the notochord can be traced from the post-sphenoid section of the base of the skull, which is situated beneath the mid-brain, to the tip of the coccyx.

The separation of the notochord from the entoderm commences in the cervical region, and extends forwards and backwards. The anterior extremity is the last part to be detached, the separation occurring shortly after the perforation and disappearance of the bucco-pharyngeal membrane.

The cellular notochord develops a cuticular sheath; it is subsequently surrounded by mesoderm which separates it both from the neural tube and the entoderm,

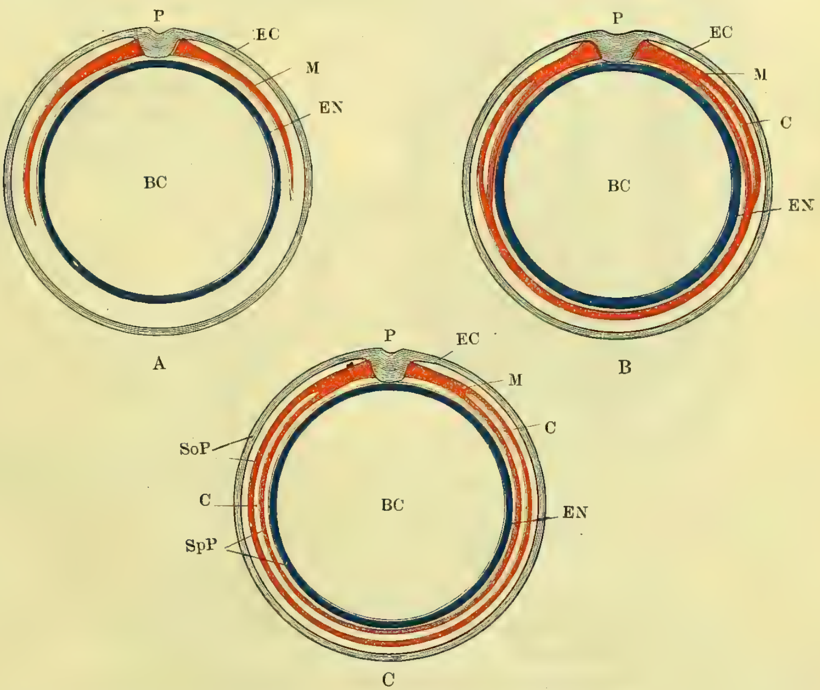


Fig. 17.—Extension of Mesoderm and Formation of Cœlom (Diagrammatic).

A. Mesoderm spreading from the sides of the ectodermal primitive streak, and extending between the ectoderm and entoderm. B. Further extension of the mesoderm and appearance of cœlomic cleft-like spaces. C. Complete delamination of the mesoderm and formation of cœlom.

BC. Blastodermic cavity. C. Cœlom. EC. Ectoderm. EN. Entoderm. M. Mesoderm. P. Primitive Streak. SoP. Somatopleure. SpP. Splanchnopleure.

and which is ultimately transformed into the vertebræ and their ligaments, the intervertebral discs, the basi-sphenoid and basi-occipital parts of the skull, and the membranes of the brain and cord.

As the surrounding mesoderm is differentiated the notochord becomes nodulated;

the thickened portions are situated in the regions of the intervertebral discs, and the intermediate constricted portions in the regions of the vertebral bodies. The vertebral portions gradually disappear, and the intervertebral parts are converted into a kind of mucoid tissue, the pulp of the intervertebral discs.

Formation of the Cœlom.—Before the extension of the mesoderm over the blastoderm is completed, that is, before it has reached the ventral pole of the ovum, it begins to separate into two layers. The separation is brought about by cleft-like spaces which appear within its substance near the margin of the embryonic area, and, rapidly coalescing, form the cœlom or body cavity. Increasing in size, the cœlom extends towards both poles of the blastodermic vesicle, but in the embryonic area it is arrested before it quite reaches the notochord and the sides of the primitive streak. It extends across the pericardial area, however, and forms the rudiment of the pericardial cavity, which appears as a transverse tubular passage continuous on each side with the general body cavity. Thus the mesoderm is separated into two layers, except along the sides of the notochord and primitive streak. The outer or parietal of these layers becomes more or less closely attached to the ectoderm, and with it forms the **somatopleure,** whilst the inner or visceral layer is similarly associated with the entoderm to form the **splanchnopleure.**

There is reason to believe that in man and other higher mammals the ectoderm and entoderm are separated by a large space before the formation of the mesoderm commences, and that the mesoderm is cleft as it extends, the somatopleuric part growing round the inner surface of the ectoderm and the splanchnopleuric layer extending over the outer surface of the entoderm; therefore it may be said that the two layers of the mesodern extend from the primitive streak and grow round a space which intervenes in the first instance between the ectoderm and the entoderm, and which, when the extension of the mesoderm is completed, becomes the cœlom. This mode of extension of the mesoderm is merely a modification of the more general plan of its separation into layers at a later period.

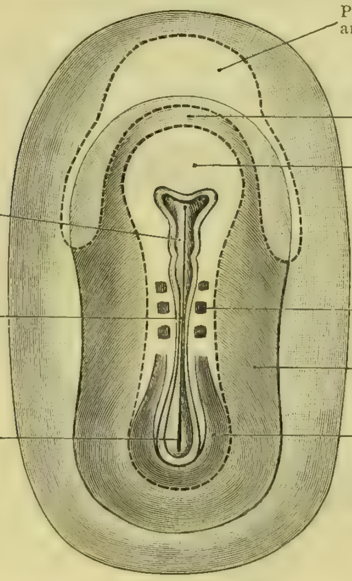


FIG. 18.—SURFACE VIEW OF AN EARLY EMBRYO (Diagrammatic). Showing the neural groove, dilated in the head region but still unclosed, and the first protovertebral somites. The margins of the cœlomic space are indicated by dotted lines.

When the cœlom is fully formed the blastoderm contains two cavities, one, the cœlom or body cavity, situated between the two layers of the mesoderm, and the other the cavity of the blastodermic vesicle, usually called the vitelline cavity, which lies inside the entoderm.

Mesodermic or Protovertebral Somites.—During the formation of the cœlom the undivided mesoderm at each side of the notochord thickens, principally by a dorsal upgrowth which is coincident with the uprising of the ectodermal medullary folds which bound the neural groove. There are thus formed two thickened bars of mesodermal tissue, one on each side of the neural tube, and they together constitute the **paraxial mesoderm** (Fig. 13); the more laterally situated portions of the mesoderm are known as the **lateral plates.**

The paraxial mesoderm is soon divided, except in the head region, by a number of transverse clefts into a series of cubical masses termed the **protovertebral somites.** These are at first partially, and afterwards more completely separated from the lateral plates by longitudinal grooves. After the longitudinal grooves

are formed, the protovertebral somites are connected with the lateral mesoderm by somewhat contracted strands of cells which collectively constitute the **intermediate cell mass** of each side (Fig. 14).

The separation of the paraxial mesoderm from the lateral plates and the segmentation of the former into somites extends forwards to the region of the hind brain, where the first protovertebral somite is formed. In front of this the mesoderm, in mammals at least, does not become segmented.

The cavity of the cœlom may extend into the paraxial mesoderm before it is segmented into protovertebral somites, or it may stop just outside the limits of the paraxial mesoderm. In the former case each somite, when separated from the lateral plate, contains a cavity, and the intermediate cell mass is also hollow for a

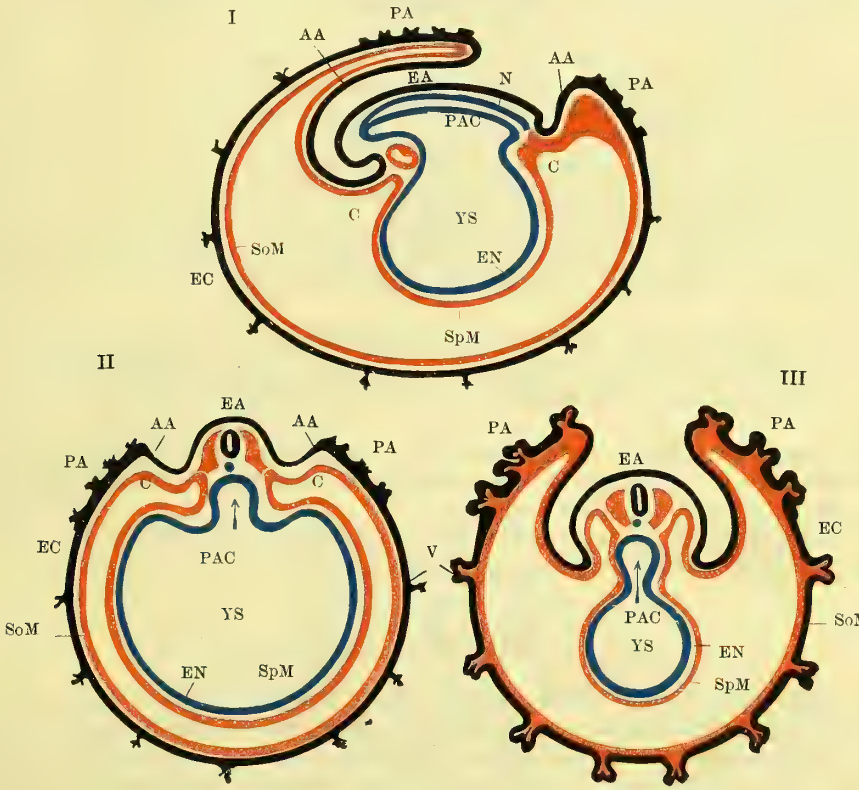


FIG. 19.—EARLY STAGES IN THE FOLDING OFF OF THE EMBRYO (Diagrammatic).

I. Longitudinal section of a developing ovum. The folding off of the embryo has commenced, and the head fold bending down in front, has invaginated the amniotic area. The tail fold is partly formed, and the primitive alimentary canal, closed in front, communicates freely with the yolk-sac by a wide umbilical aperture.

II. Transverse section of a developing ovum showing the commencement of the "folding off." The thickened embryonic area is convex externally, and it already appears to sink below the surface of the ovum.

III. Transverse section showing the "folding off" more advanced. The changes seen in II. are more marked, and by apparent constriction at the junction of the embryonic area with the rest of the blastodermic vesicle the embryo is still further nipped off, and distinct lateral folds are formed.

The division of the cavity of the blastodermic vesicle into that of the primitive alimentary canal and that of the yolk-sac is shown in all the figures.

The amniotic area, directed upwards and inwards in II., forms with the placental area the amniotic fold, and in III. the amniotic folds of opposite sides are approaching one another over the back of the embryo to enclose the cavity of the amnion. The relative positions of the different areas of the blastoderm are correspondingly modified.

AA. Amnion fold.	EC. Ectoderm.	PA. Placental area.	SpM. Splanchnic mesoderm.
C. Cœlom.	EN. Entoderm.	PAC. Primitive alimentary canal.	YS. Yolk-sac.
EA. Embryonic area.	N. Notochord.	SoM. Somatic mesoderm.	V. Villi.

time. In the latter case the protovertebral somites and the intermediate cell masses are solid; at a later period, however, a cavity which contains a few spherical cells appears temporarily in each somite.

Folding Off of the Embryo from the Blastodermic Vesicle.—Although so

many rudiments of the embryo become distinguishable at an early period in its development, *e.g.* the embryonic area, the primitive streak and groove, the neural groove, the notochord and the protovertebral somites, the body of the embryo does not assume its characteristic form until it becomes raised and folded off from the general surface of the blastodermic vesicle.

The main cause of the folding off of the embryo from the surface of the vesicle is the more rapid growth of the embryonic area as contrasted with the slower growth and expansion of the remainder of the wall of the vesicle; and the moulding of the increasing embryonic area into the form of the embryo is due to differences in the rate of growth of the various parts of the area itself.

The manner in which the area is folded, and the changes in the relative positions of its various parts which necessarily result, will be facilitated by reference to Figs. 19 and 25.

The embryonic area at an early period increases rapidly, especially in length. Its margins, however, appear to remain comparatively fixed, and hence as the area increases it must fold upon itself. It becomes somewhat convex externally, and is raised slightly above the general surface, but at the same time it apparently sinks into the interior of the ovum, and the amnion folds close over it.

The antero-posterior growth is greater than the lateral; consequently the folding of the embryonic area is most marked in front and behind. Anterior and posterior, or cephalic and caudal, folds are formed, which indicate the head and tail extremities of the embryo. Similarly, lateral folds define the lateral limits of the body.

When the body of the embryo thus becomes folded off it contains a portion of the blastodermic cavity and of the cœlom; the former is the primitive alimentary canal, and the latter is the rudiment of the pericardial, pleural, and peritoneal cavities.

The communication between the pleuro-peritoneal and the corresponding extra-embryonic cavity is obviously bounded by the margins of the embryonic area, and it constitutes the umbilical orifice.

The margins of the embryonic area retain approximately their original positions, and in its further growth the embryo extends beyond them in all directions.

THE EMBRYO.

The embryo, now easily distinguishable from the rest of the ovum, is already sufficiently developed to give some indication of the general plan of its organisation and of the ultimate relation and fate of the three layers of the blastoderm which enter into its constitution. There are as yet no limbs, but the general contour of the head and body are defined. It possesses a notochord, afterwards replaced by the permanent vertebral column, which constitutes a longitudinal central axis. On the dorsal aspect of the notochord the neural groove is closing to form the neural canal, or primitive cerebro-spinal nervous system, whilst, on its ventral side, a portion of the blastodermic cavity is being included as a primitive tubular alimentary canal, which freely communicates with the remainder of the blastodermic cavity, now called the cavity of the yolk-sac.

The formation of the protovertebral somites, which is the first indication of that segmentation which is such a characteristic feature in the structure of the vertebrate body, has commenced.

The general relations of the three layers of the blastoderm remain unaltered. Thus, externally, there is a layer of ectoderm forming the surface of the body; internally, a layer of entoderm lining the primitive alimentary canal; and between them is the mesoderm, enclosing the cœlom.

The **surface ectoderm** forms the epithelial elements[1] of the skin and its

[1] The term "Epithelium" is applied to tissues consisting of cells which are united with one another by means of a small amount of intercellular substance.

The cells constituting epithelium are always arranged in one or more layers; they cover free surfaces and line the various cavities of the body, including the vascular and lymphatic systems; they also form the active elements in secretory glands and line their ducts. Epithelium is always non-vascular, and the

appendages, and of the glands which open on it. Thus the hairs and hair-follicles, the nails, the enamel of the teeth, the epithelium of the sebaceous glands, of the sweat glands, and of the mammary glands are all ectodermal. The epithelium of the conjunctivæ and of the lachrymal glands is also derived from ectoderm. The roof of the mouth, the inner surfaces of the cheeks, the nasal passages and their associated cavities, together with the adjacent part of the pharynx and the anterior lobe of the pituitary body, as well as the external auditory canal and the outer layer of the tympanic membrane, are all developed from the surface, and their epithelium, with that of their glands, is ectodermal in origin. The epithelium of the sense organs, except that of taste (the tongue), is derived from ectoderm; the auditory and olfactory epithelial elements, and those of the lens and cornea, are from surface ectoderm; whilst the epithelial elements of the retina are from neural ectoderm.

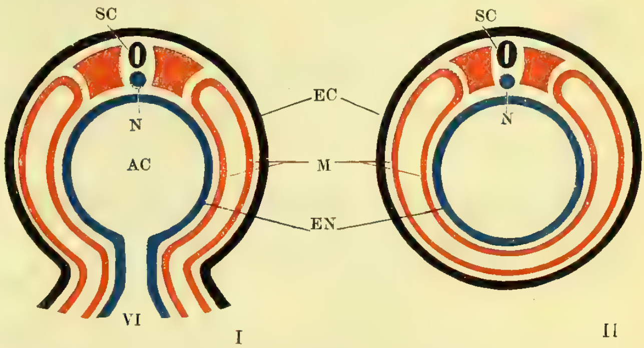


FIG. 20.—THE RELATIVE POSITIONS OF THE BLASTODERMIC LAYERS IN THE BODY OF THE EMBRYO WHEN THE "FOLDING OFF" IS COMPLETED (Diagrammatic).

I. Transverse section through the umbilical aperture.
II. Similar section in front of or behind the umbilicus.

AC. Alimentary canal. EN. Entoderm. N. Notochord.
EC. Ectoderm. M. Mesoderm. SC. Spinal cord.
VI. Vitello-intestinal duct and umbilical aperture.

The **neural ectoderm** is removed from the surface to form the neural tube and neural crest, from which the cells and fibres of the whole of the nervous system, both central and peripheral, and the sustentacular tissue of the brain and spinal cord, are developed. The neural ectoderm also furnishes the epithelial elements of the retinæ, the pineal gland, and of the posterior lobe of the pituitary body.

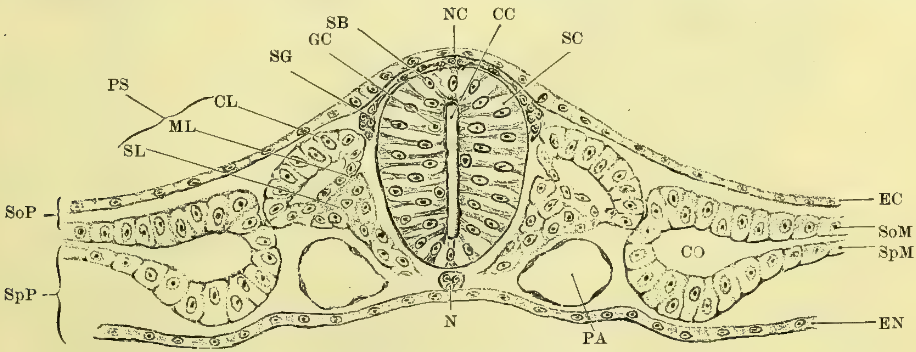


FIG. 21.—TRANSVERSE SECTION OF A FERRET EMBRYO, Showing further differentiation of the mesoderm.

CC. Central canal.
CL. Cutaneous lamella of protovertebral somite.
CO. Cœlom.
EC. Ectoderm.
EN. Entoderm.
GC. Germinal cell.
ML. Muscular layer of protovertebral somite.
N. Notochord.
NC. Neural crest.
PA. Primitive aorta.
PS. Protovertebral somite.
SB. Spongioblast.
SpP. Splanchnopleure.
SC. Spinal cord.
SG. Spinal ganglion.
SL. Scleratogenous layer of protovertebral somite.
SoM. Somatic mesoderm.
SoP. Somatopleure.
SpM. Splanchnic mesoderm.

The **entoderm** lines the alimentary canal and the spaces and glands which open

cells receive their nourishment from blood-vessels which are in their vicinity. Epithelial cells are modified in accordance with the particular functions they are called upon to serve, and they present many variations in shape, size, and structure, *e.g.* the neuro-epithelial cells of the central nervous system and of the peripheral sense organs differ considerably from the more ordinary epithelial type; but they are simply more specialised, and therefore more modified.

into it, except the upper parts of the mouth and pharynx and the terminal portion of the rectum; thus the epithelium of the Eustachian tube and tympanic cavity, the trachea, the bronchi, the air-vesicles of the lungs, the gall-bladder, the urinary bladder, and part of the urethra is entodermal. It forms the epithelial constituents of the taste buds, or organs of taste, the liver and the pancreas, the epithelium lining the vesicles of the thyroid body and the cell nests of the thymus gland.

From the **mesoderm** all the remaining structures which intervene between the surface ectoderm and the entodermal lining of the primitive alimentary tube are formed.

The Protovertebral Somites and the Lateral Plates.—Each protovertebral somite consists of numerous cells arranged radially round a central cavity—the *myelocœle;* this latter, however, quickly disappears.

The cells of the somites are gradually grouped into three sets, two to the inner and lower side of the cavity, and one to its upper and outer side. The two groups on the lower and inner side are an outer, next the cavity, the **muscle plate**, and an inner the **scleratogenous layer.** The group on the upper and outer side of the cavity is the epithelial or **cutaneous lamella.**

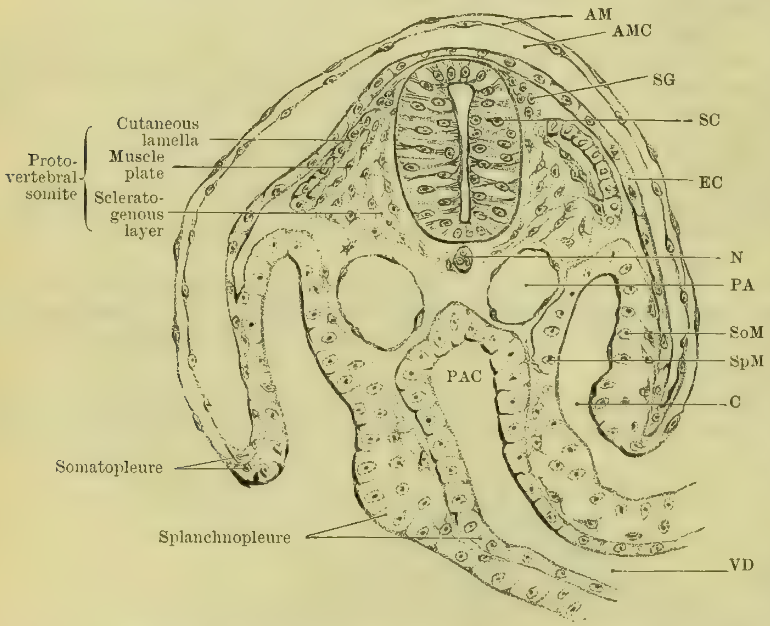


FIG. 22.—FURTHER DIFFERENTIATION OF THE MESODERM.

Transverse section of a rat embryo, showing the transformation of the cells of the scleratogenous layer of a protovertebral somite and their extension round the notochord and spinal cord.

AM. Amnion.
AMC. Amnion cavity.
C. Cœlom.
EC. Ectoderm.
N. Notochord.
PA. Primitive aorta.
PAC. Primitive alimentary canal.
SC. Spinal cord.
SG. Spinal ganglion.
SoM. Somatic mesoderm.
SpM. Splanchnic mesoderm.
VD. Vitello-intestinal duct.

The Scleratogenous Layer.—The cells of this layer proliferate rapidly and migrate inwards, surrounding the notochord, and passing both beneath the neural tube and upwards along its lateral walls to its dorsal aspect; they intermingle above and below with the cells of the corresponding layer of the opposite side, and in front and behind with the cells of the scleratogenous layers of adjacent somites. In this way the neural tube and the notochord are gradually enveloped by a continuous sheath of mesodermal tissue, which forms the **membranous vertebral column.** This is perforated at regular intervals by the nerve-roots issuing from the spinal cord and brain, and by the vessels of supply to those structures. From its substance the vertebræ and ligaments, the greater part of the intervertebral discs, and the investing membranes of the brain and cord are afterwards developed.[1]

The Muscle Plates.—The cells of the muscle plate layer lose their original epithelial-like characters; they elongate antero-posteriorly, become spindle-shaped and striated, and they give rise to the striped muscles of the body. For a long time the fibres developed from each muscle plate remain localised and quite distinct from the fibres developed from neighbouring segments; the masses they form are

[1] The development of the skeleton is described in the chapter on Osteology.

called **myotomes.** After a time, however, the fibres of neighbouring myotomes are more or less intermingled, and in the adult, except in certain situations, the inter-myotomic intervals are no longer recognisable.

The main portions of the myotomes are converted into the muscle masses situated in the dorsal part of the body wall, that is, into the erectores spinæ and their main subdivisions, and the other muscles which occupy the vertebral grooves.

In the lower vertebrates the ventral ends of the myotomes descend in the somatopleure almost to the mid-ventral line, and are transformed into the muscles of the ventro-lateral walls of the body. A similar descent of the ventral ends of the myotomes into the lateral walls of the body has not been proved in the highest vertebrates. In mammals, including man, the ventral ends of the myotomes only descend for a short distance in the somatopleure, and then all trace of their characteristic structure is lost. It is presumed, however, that cells budded off from the myotomes descend to a lower level, and that they take part in the formation of the ventro-lateral muscles.

In lower vertebrates bud-like projections pass from the myotomes in the thoracic and pelvic regions into the limb rudiments, and from these the muscles of the limbs are developed. In the highest vertebrates distinct buds from the myotomes have not been observed, but it is said that outgrowths of cells pass from the myotomes into the limb buds, where they proliferate and form the limb-muscles. The occurrence of these outgrowths into the limbs, like the descent of the lower ends of the myotomes into the ventral part of the body-wall, has not been proved in mammals; possibly it occurs, but, if not, the ventral and limb-muscles of mammals must be developed from the somatopleural mesoderm.

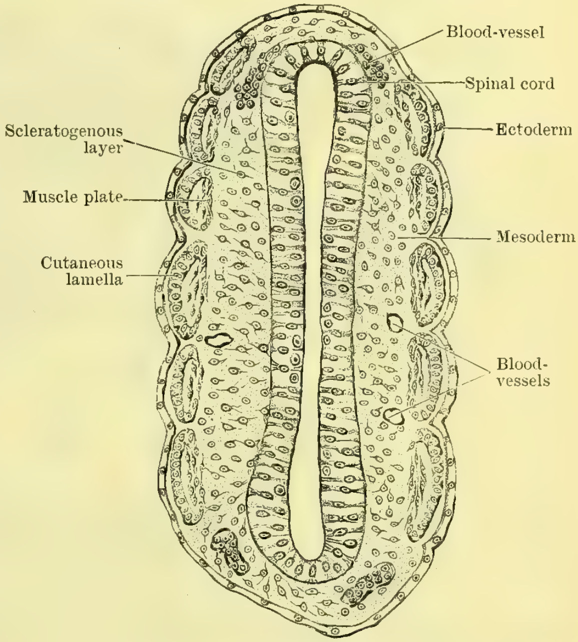


FIG. 23.—CORONAL SECTION OF A RAT EMBRYO.
Showing the relationship of the extending scleratogenous tissue to the spinal cord and to the muscle plates.

The Cutaneous Lamella of the Protovertebral Somite.—The cells which form the outer and dorsal walls of the cavities of the protovertebral somites retain their epithelial-like characters for a longer period than those of other portions of the somites, and at the borders of the lamellæ they pass by gradual transition into the cells of the muscle plates. After a time they undergo histological differentiation, and they are utilised in the formation of the subcutaneous tissues and fasciæ on the dorsal aspect of the body, and outgrowths, which descend with the offsets of the muscle plates, enter into the formation of the ventro-lateral walls of the body.

The Protovertebral Somites of the Head.—It has already been pointed out (p. 24) that protovertebral somites are not recognisable in mammals further forwards than the occipital region; but, from the evidence obtained by examination of lower vertebrates, it is believed that originally nine somites were present in the cephalic region. From the first, second, and third of these, muscle plates form which are developed into the muscles of the eyeballs. If any muscle plates are formed in connection with the fourth, fifth, and sixth somites they disappear, leaving no traces, and the muscles developed from the remaining cephalic somites are those of the tongue and those connecting the head with the shoulder girdle.

The Lateral Plates.—At an early stage, before its separation from the paraxial mesoderm, each lateral plate is divided into an outer or somatic and an inner or splanchnic layer. The somatic layer is concerned with the formation of the

parietal layers of the pleural and peritoneal membranes, and with the development of the connective tissues, fasciæ, and vessels of the ventro-lateral walls of the body; and in mammals, apparently, it also gives origin to the ventro-lateral body muscles and the muscles of the limbs. The splanchnic portions of the lateral plates form the fasciæ, the connective tissues, the smooth muscles of the walls of the alimentary canal, the heart and great blood vessels, the visceral layers of the pleural and peritoneal membranes, the spleen, and the germinal epithelium, which becomes transformed into the mother cells of the ova and spermatozoa.

In the cephalic region, in higher vertebrates, lateral plates are not recognisable, except so far as they may be represented by the walls of the pericardium; but in some lower vertebrates lateral plates can be distinguished, corresponding in number with the cephalic somites, and it has been asserted that the muscles of the

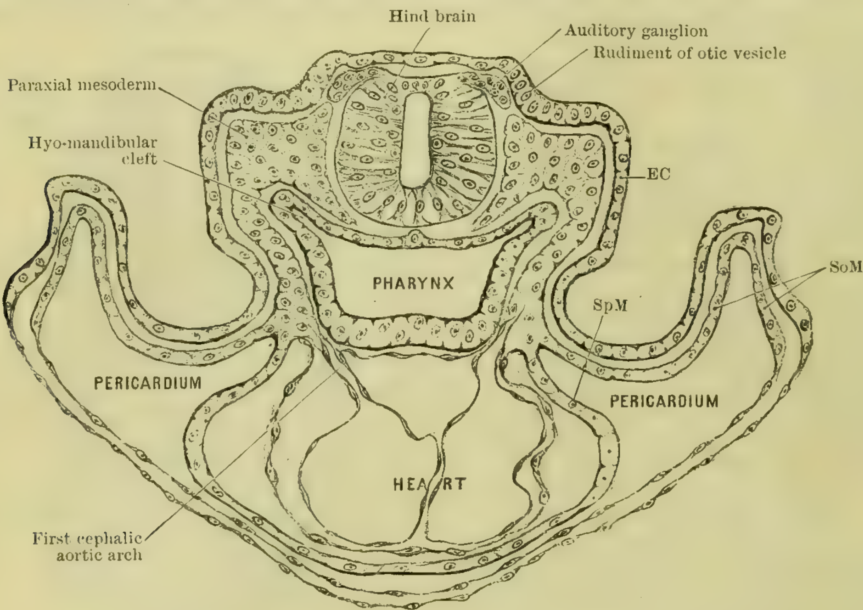


FIG. 24.—TRANSVERSE SECTION OF A RAT EMBRYO.

Showing the relation of the paraxial mesoderm of the head to the lateral plates, the commencement of the formation of the otic vesicles and hyomandibular clefts, and the relation of the primitive heart to the pericardium and fore-gut.

EC. Ectoderm. SoM. Somatic mesoderm. SpM. Splanchnic mesoderm.

face and the muscles of mastication are developed from the lateral plates associated with the second and third cephalic somites. The subject, however, is one which is still obscure, and requires further investigation before any very positive conclusion can be arrived at.

The Intermediate Cell Mass.—As already mentioned, the lateral plates and the protovertebral somites are connected by the intermediate cell-masses, which are intimately associated with the development of the ducts and tubules of the genital and urinary organs in man and other mammals. On each side the mass soon separates from the protovertebral somites, and is transformed by rapid proliferation of its cells into an elongated body, the Wolffian body or primitive kidney, which projects downwards into the dorsal angle of the body cavity. In early stages it extends from the fifth somite of the body backwards to its posterior end, but is most clearly differentiated in the middle portion. The Wolffian duct and tubules and the Müllerian duct are developed in connexion with it; after the second month of intrauterine life it degenerates, and is replaced by the permanent kidney, which is formed dorsal to its posterior extremity.

THE DEVELOPMENT OF THE PRIMITIVE ALIMENTARY CANAL.

When the cephalic, caudal, and lateral folds are established, and the general outline of the embryo is clearly defined, its dorsal and lateral surfaces and its anterior and posterior extremities are easily recognisable, and, as the embryo is folded off from the surface of the blastodermic vesicle, a portion of the blastodermic cavity is enclosed within it; this is the primitive alimentary canal. It is simply an incomplete tubular cavity, situated beneath the notochord, which is bounded in front by the head fold, behind by the tail fold, and laterally by the lateral folds, but is widely open below and continuous with the cavity of the yolk sac.

As the head of the embryo grows more rapidly than any other part, the head fold is more marked than the other folds, and with its formation the pericardial area is bent round until it becomes ventral in position, its original upper and lower surfaces being reversed (Fig. 25). It is owing to this change of relative position

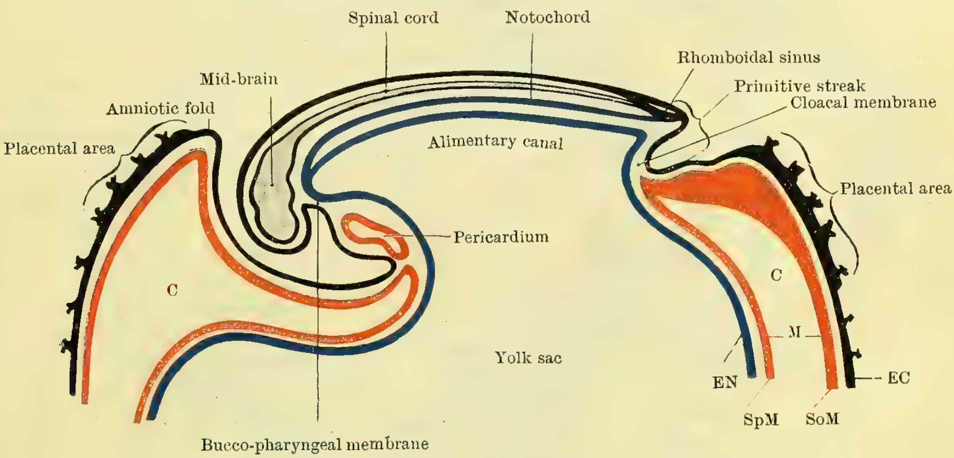


FIG. 25.—DIAGRAM OF A DEVELOPING OVUM, SEEN IN LONGITUDINAL SECTION.

The folding off of the embryo has commenced, and the downward bend of the head fold in front has invaginated the amniotic area. The tail fold is partly formed, and the primitive alimentary canal, closed in front by the bucco-pharyngeal membrane and behind by the cloacal membrane, is distinguishable; it communicates freely with the yolk sac by a wide umbilical aperture.

C. Cœlom. EN. Entoderm. SoM. Somatic mesoderm.
EC. Ectoderm. M. Mesoderm. SpM. Splanchnic mesoderm.

that the ventral wall of the alimentary canal is completed in front, and it is obvious that its anterior limit corresponds to the bucco-pharyngeal area of the blastoderm. The part so closed in constitutes the **fore-gut.**

The tail fold at this period is small, but it limits the primitive gut behind.

The ventral closing of the posterior end of the primitive alimentary canal to form a **hind-gut** is produced, as in the case of the fore-gut, by bending of the embryonic area. This takes place in the region of the tail fold; but the posterior part of the embryonic area retains for a considerable time its original position, and forms a connecting stalk, termed the **body-stalk,** between the embryo and the chorionic area of the blastoderm. Ultimately, however, this terminal section of the embryonic area is reversed in position, its posterior end being carried forwards till it forms the posterior boundary of the umbilical orifice, and the ventral wall of the hind-gut is thus completed.

The rest of the primitive alimentary canal constitutes the **mid-gut.** It remains for some time in free communication with the cavity of the yolk-sac, and this communication between the alimentary canal and the yolk-sac at a later stage forms a tubular passage, the **vitello-intestinal duct.**

The entoderm forms the lining epithelium of the alimentary canal, but this is invested by the splanchnic layer of the mesoderm, and it is separated from the somatopleure or body wall by the cœlom or body cavity. As the splanchnic mesoderm passes on each side to its continuity with the somatic mesoderm it forms

a fold, by which the gut is suspended from the under surface of the primitive vertebral column; this fold is the **mesentery.**

The diaphragm, which is formed at a later period and which separates the thorax from the abdomen, divides the cœlom into pleural and peritoneal portions.

The primitive alimentary canal is almost a straight tube, blind at both its extremities, and communicating only with the cavity of the yolk sac. As yet there is no mouth and no anal passage or aperture. The simple tubular canal is divisible into fore-gut, mid-gut, and hind-gut, parts which are conveniently associated developmentally with definite portions of the fully-formed alimentary canal.

Thus the fore-gut is converted into the pharynx, œsophagus, stomach, and the greater part of the duodenum; whilst from the mid-gut and the hind-gut the rest of the small intestine (jejunum and ileum), and the whole length of the large intestine (cæcum, colon, and rectum), are formed. There is no sharp limit between the mid-gut and the hind-gut, or between the portions of the intestinal canal which develop from them.

Diverticular outgrowths from the entoderm of the primitive alimentary canal form the rudiments of the intestinal glands, including the liver and pancreas, of the respiratory apparatus, and of the thyroid and thymus glands. Details of the formation of these structures are given in the special description of the development of the system to which each belongs.

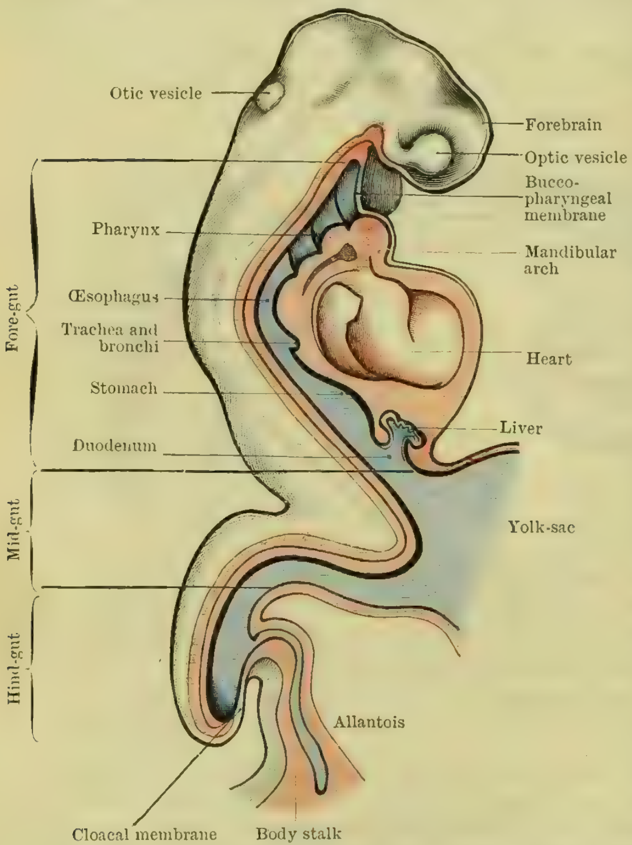


FIG. 26.—DIAGRAM REPRESENTING THE CONDITION OF THE ALIMENTARY CANAL IN A HUMAN EMBRYO ABOUT FIFTEEN DAYS OLD (modified from His).

The visceral clefts are formed, and the subdivisions of the fore-gut, together with the rudiments of the bronchi and liver, are distinct.

Except with respect to the anterior part of the fore-gut, the changes in shape and position which the originally simple alimentary tube undergoes during its conversion into its final or adult form are described in the account of the development of the digestive organs; but the development of the pharynx and the structures associated with it, and the formation of the mouth and anus, may be considered now.

Development of the Pharynx and Stomatodæum.—The development of the anterior part of the fore-gut into the pharynx and the floor of the mouth is so intimately associated with the formation of a primitive mouth, the stomatodæum, that the two must to a certain extent be considered simultaneously.

The **stomatodæum** first appears as a depression between the head and the pericardial region. It is produced by the downward growth of the forepart of the head in front and the bulging forward of the pericardium behind, and it is separated from the anterior end of the fore-gut by the bi-laminar bucco-pharyngeal membrane. When the stomatodæum first appears it is not enclosed laterally; but at a later period side boundaries are formed, and the space is developed into the upper part of the mouth and the nasal cavities.

The fore-gut, a relatively wide space, continuous posteriorly with the mid-gut, is thus at first closed anteriorly by the bucco-pharyngeal membrane, which separates it from the stomatodæum. About the fifteenth day, in the human embryo, the bucco-pharyngeal membrane disappears, the fore-gut is then thrown into continuity with the stomatodæal space, and the anterior opening of the alimentary canal is formed.

As development proceeds the cavity of the fore-gut is gradually compressed dorso-ventrally, until its transverse section assumes a triangular outline; but in the earliest stages there are no indications of the various organs which are ultimately developed from its walls. After a short interval, however, two elevations

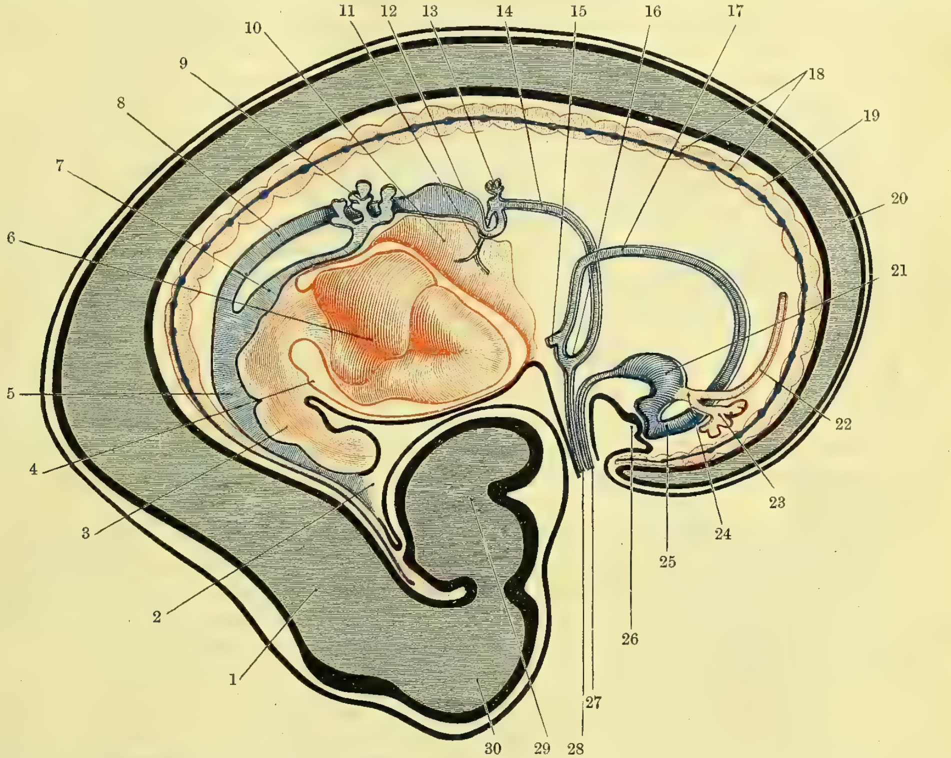


FIG. 27.—FURTHER DEVELOPMENT OF THE ALIMENTARY CANAL, AS SEEN IN A HUMAN EMBRYO ABOUT FIVE WEEKS OLD (Diagrammatic).

The tongue is well formed, the trachea and œsophagus are separated, the bronchi have commenced to branch; the duodenal curve is well formed, and the cæcum has appeared in the loop of the mid-gut. The cloaca is partially separated into genito-urinary and rectal portions.

1. Hind-brain.	7. Trachea.	13. Pancreas.	19. Vertebra.	25. Rectum.
2. Mouth.	8. Œsophagus.	14. Small intestine.	20. Spinal cord.	26. Proctodæum.
3. Tongue.	9. Lung.	15. Cæcum.	21. Bladder.	27. Allantoic diverticulum.
4. Pericardium.	10. Liver.	16. Intestinal loop.	22. Wolffian duct.	28. Vitello-intestinal duct.
5. Pharynx.	11. Bile duct.	17. Large intestine.	23. Kidney.	29. Fore-brain.
6. Heart.	12. Stomach.	18. Notochord.	24. Ureter.	30. Mid-brain.

appear in its ventral wall. The anterior of these is a rounded elevation, termed the **tuberculum impar.** It is situated directly behind the lower ends of two raised bars or arches, called the mandibular arches, which are growing down into the floor of the fore-gut from the anterior parts of its lateral walls. The tuberculum impar is the rudiment of the anterior two-thirds of the tongue, which is thus formed in the floor of the entodermal portion of the alimentary canal. The more posterior elevation, termed the **furcula,** is a curved ridge, which bounds a mesial longitudinal depression. It is separated from the lateral walls of the fore-gut and from the tuberculum impar by a groove, the **sinus arcuatus.** The anterior part of the furcula is transformed into the epiglottis and the margins of the upper aperture of the larynx; the median depression becomes the cavity of the larynx and of the trachea. Still more posteriorly, behind the region of the furcula, a dilatation of the fore-gut

is formed, which projects, forwards and downwards, towards the pericardium. This is the first indication of the stomach.

Visceral Clefts and Visceral Arches.—In the lateral wall of the anterior part of the fore-gut, on each side, four incomplete and more or less transverse clefts, the visceral clefts, appear. They are due to outward linear pouchings of the entoderm, and corresponding, but less marked, inward depressions of the ectoderm. The anterior cleft is the best marked, and the rest diminish in size from before backwards. At the bottoms of the clefts the ectoderm and the entoderm are in contact, but the thin membranes thus formed, which intervene between the cavity of the fore-gut and the exterior, are only exceptionally and abnormally perforated in the human subject, though in lower vertebrates they invariably disappear, and the pharyngeal or anterior part of the fore-gut is thrown into continuity, laterally, with the exterior by a number of narrow slits, the gill slits, which are used for respiratory purposes. In man and other mammals, however, the floors of the second, third, and fourth clefts are utilised in the formation of the sides of the neck; that of the first cleft is transformed into the tympanic membrane, which separates the external auditory meatus from the cavity of the tympanum.

In the further consideration of the fate of the visceral clefts, it must be borne in mind that each consists of an inner or entodermal portion and an outer or ectodermal portion. The inner part of the first cleft is converted into the tympanum and the Eustachian tube, and the outer part becomes the external auditory meatus. No traces of the outer part of the second cleft are left, but a portion of the inner part can be recognised as a slight depression above the tonsil in the lateral wall of the pharynx. Both the outer and inner portions of the third and fourth clefts disappear, but from their inner parts diverticula are given off which form the rudiments of the thymus and the lateral lobes of the thyroid body. The diverticula from which the thymus is developed are derived from the third clefts, whilst each lateral lobe of the thyroid body is formed by a diverticulum from the fourth cleft.

The margins of the visceral clefts are thickened by the growth of the mesoderm between the entodermal and ectodermal layers, and they are moulded into a series of five rounded bars, the **visceral arches,** of which the fifth is not recognisable externally, though it is easily seen internally. The dorsal extremities of the arches terminate at the sides of the head below the level of the neural tube, and in the early stages the ventral ends rest upon the pericardial region. When the neck is formed, it grows forwards from the pericardial region and carries with it the lower ends of the visceral arches, which henceforth terminate in its ventral wall. As the visceral arches are carried forwards the head is strongly curved towards the ventral aspect, and the lower ends of the visceral arches are pushed backwards over each other till the fourth is overlapped by the third, and the third by the second.

The first arch is the mandibular, the second the hyoid, the third the thyro-hyoid; the fourth and fifth have no special designations. Each arch is covered—externally by ectoderm, internally by entoderm, and its core is formed of mesoderm, in which there is developed a bar of cartilage and a blood vessel called a cephalic aortic arch.

At first each arch is limited to the side wall of the fore-gut; but after a time it is prolonged into the ventral wall, encroaching, with the exception of the first, upon the sinus arcuatus.

The **first,** or **mandibular arch,** is formed between the first visceral cleft and the bucco-pharyngeal membrane. As it develops it forms the lateral and lower boundaries of the stomatodæal space, and it grows downwards till it meets its fellow of the opposite side in the ventral middle line, immediately in front of the tuberculum impar. The greater part of this arch is converted into the lower jaw and the soft tissues which invest it. From its upper part a process grows forwards, the **maxillary process,** from which the upper lateral part of the face, between the orbit and the mouth, is developed, and in which the superior maxillary, the malar, and the palate bones, and possibly the internal pterygoid plate also, are developed and ossified.

From the posterior border of the outer aspect of the mandibular arch the tragus

and a portion of the helix of the pinna of the external ear are formed. The cartilaginous bar in its interior is known as **Meckel's cartilage.** It forms the primitive skeleton of the arch. Its upper and lower extremities are ossified and remain in the adult, the former as the malleus, and possibly the incus, and the latter as the symphysial part of the lower jaw. The remainder of the cartilaginous bar disappears, but the fibrous membrane which surrounds the lower section of the intermediate part is ossified and converted into the main part of the lower jaw, whilst that round the upper section of the intermediate portion persists as the spheno-mandibular ligament. The blood vessel developed in the mandibular arch is, for the main part, a transitory structure, but its ventral section is converted into the internal maxillary, superficial temporal, and lingual arteries.

The **second** and **third arches** are continued downwards into the floor of the pharyngeal portion of the fore-gut. There, converging, they insinuate themselves between the tuberculum impar and the furcula, across the anterior part of the sinus arcuatus, and uniting together form a transverse bar. This rapidly changes into a semilunar ridge, which embraces the posterior part of the tuberculum impar, with which it fuses, and it forms the posterior third of the tongue.

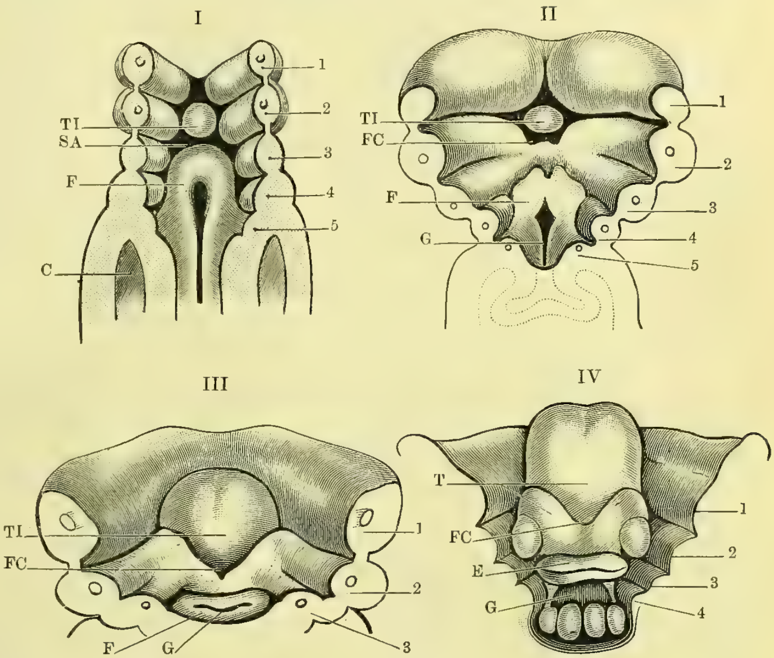


FIG. 28.—STAGES IN THE FORMATION OF THE TONGUE AND UPPER APERTURE OF THE LARYNX IN THE HUMAN EMBRYO (after His).

I. Embryo 14 days old. II. Embryo 23 days old. III. Embryo 28 to 30 days old. IV. Embryo 2 months old.

1, 2, 3, 4, 5 Visceral arches.
C. Cœlom.
E. Epiglottis.
F. Furcula.
FC. Foramen cæcum.
G. Glottis.
SA. Sinus arcuatus.
T. Tongue.
TI. Tuberculum impar.

The **second arch** takes part in the formation of the side and anterior part of the neck. From its anterior border externally a part of the helix, the antihelix, the antitragus, and the lobule of the pinna of the external ear are developed. The lower and upper portions of its cartilaginous bar—the hyoid bar—are ossified; the lower portion forms part of the body and the small cornu of the hyoid bone on its own side, and the upper portion is converted into the intra- and extra-temporal sections of the styloid process (the tympano-hyal and stylo-hyal portions of the styloid process of the temporal bone). The fibrous tissue of the intermediate part of the hyoidean bar persists in the adult as the stylo-hyoid ligament. The blood-vessel of the hyoid arch, the second cephalic aortic arch, almost entirely disappears, but from its ventral extremity the ascending pharyngeal, occipital and posterior auricular arteries are probably developed.

The **third visceral arch** forms part of the neck posterior to the region of the second arch, and, as already pointed out, its lower end takes part in the formation of the posterior part of the tongue. The upper and middle parts of its cartilaginous bar disappear, but the lower part persists and is converted into the posterior part

of the body and the great cornu of the hyoid bone on its own side. Its blood-vessel, the third cephalic aortic arch, becomes the lower part of the stem of the internal carotid artery.

The **fourth** and **fifth visceral arches** also enter into the formation of the neck, but their exact limits in the adult cannot be defined. Of the upper sections of their cartilaginous bars no trace remains in the adult, but their lower portions are believed to enter into the formation of the thyroid cartilage of the larynx. The blood-vessel of the fourth arch on the right side becomes part of the right sub-clavian artery, that on the left side is converted into the arch of the aorta. The vessels of the fifth arches form portions of the pulmonary arteries, and that on the left side forms also the ductus arteriosus.

Further Development of the Ventral Wall of the Fore-gut in the region of the Furcula.—The sinus arcuatus which surrounds the furcula disappears to a great extent as development proceeds, but certain parts of it remain and are recognisable in the adult. The anterior portion immediately in front of the furcula is divided into two parts as the lower ends of the second and third arches of the two sides converge and fuse in the ventral wall of the pharyngeal portion of the foregut; the middle portion of the sinus, in front of the tranverse bar formed by this fusion, persists in the adult as the foramen cæcum of the tongue, and at a very early period a diverticulum grows backwards from it in the floor of the pharynx, dorsal to the cartilage bars which form the hyoid bone, but ventral to the rudiments of the thyroid cartilage. This diverticulum is the **thyro-glossal duct**. As soon as it reaches the level of the fourth visceral clefts it enlarges, unites with the diverticula from those clefts which form the lateral lobes of the thyroid body, and is itself converted into the isthmus of the thyroid, its pyramidal process and the thyro-glossal duct or the fibrous cord into which that duct becomes converted in the adult. Occasionally the thyro-glossal duct is not wholly transformed into a fibrous cord but portions of it remain in the form of isolated vesicles, lined with columnar or cubical epithelium, or as cords of cells, and these occasionally undergo abnormal development, forming tumours at the base of the tongue or in the upper part of the neck.

The portion of the sinus arcuatus which lies behind the conjoined lower extremities of the second and third arches of opposite sides, and in front of the furcula, persists in a modified form in the adult, and is recognisable as glosso-epiglottidean pouches or valleculæ at the base of the tongue.

The furcula and the groove in the ventral wall of the fore-gut, which it embraces antero-laterally, are both of considerable importance. The anterior part of the furcula is situated in the ventral wall of the pharyngeal portion of the fore-gut, but its backward prolongations and the furrow between them lie in what may be termed the intermediate part of the fore-gut, that is, in that part of the fore-gut which intervenes between the pharyngeal and stomach regions. Gradually the furrow deepens, and its posterior extremity dilates on each side. Afterwards the margins of the furrow coalesce from behind forwards, and in this manner the cavity of the furrow is separated from the fore-gut, its walls are converted into the trachea and the lower part of the larynx, whilst the diverticula which are projected from its posterior end, form the rudiments of the bronchi. The fusion of the margin of the furrow ceases a short distance behind its anterior extremity, which latter persists as the superior aperture of the larynx. The anterior part of the furcula, which bounds this aperture in front, becomes the epiglottis, and its lateral extensions, which form the margins of the aperture, are converted into the aryteno-epiglottidean folds in the substance of which the arytenoid cartilages and the cartilages of Santorini and Wrisberg (cuneiform cartilages) are formed.

DEVELOPMENT OF THE MOUTH AND THE NOSE.

The nose is formed entirely from the stomatodæum. The mouth has a double origin; the roof and fore part, including the teeth, are developed from the stomatodæum, whilst the floor and the tongue are developed from the pharyngeal portion of the fore-gut.

It has already been pointed out (p. 32) that the stomatodæal depression lies between the anterior part of the head (*i.e.* the tissues forming the base of the primary fore-brain) and the pericardial region, and that it is separated posteriorly from the fore-gut by the bucco-pharyngeal membrane. At first it has no distinct lateral boundaries, but subsequently the mandibular arches, which are developed at the sides of the bucco-pharyngeal membrane, project forward beyond it and form lateral limits of the depression. If the stomatodæal space is examined from the front at this period the following boundaries are recognisable. Above and in front

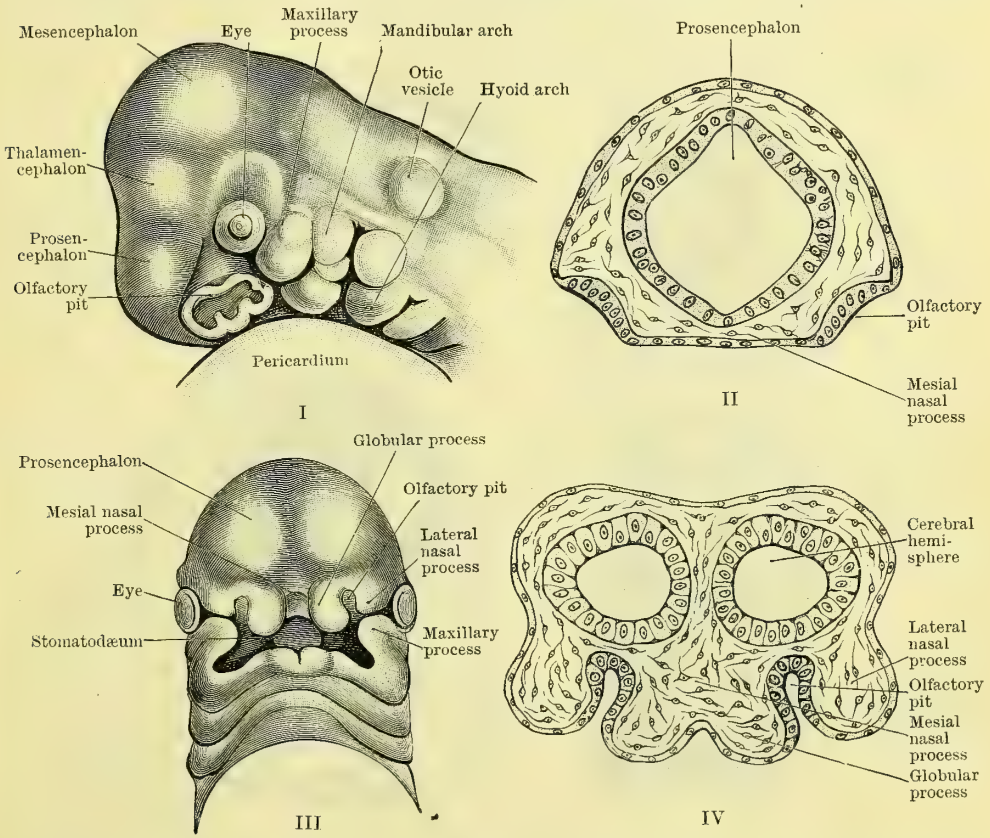


Fig. 29.

I. Side view of the head of human embryo about 27 days old, showing the olfactory pit and the visceral arches and clefts (from His).
II. Transverse section through the head of an embryo, showing the relation of the olfactory pits to the fore-brain and to the roof of the stomatodæal space.
III. Head of human embryo about 29 days old, showing the division of the lower part of the mesial frontal process into the two globular processes, the intervention of the olfactory pits between the mesial and lateral nasal processes, and the approximation of the maxillary and lateral nasal processes, which, however, are separated by the oculo-nasal sulcus (from His).
IV. Transverse section of head of embryo, showing the deepening of the olfactory pits and their relation to the hemisphere vesicles of the fore-brain.

is the projecting anterior part of the head which is termed the **fronto-nasal process,** laterally are the mandibular arches, and below and posteriorly is the anterior part of the pericardial region. After a short time the lower ends of the mandibular arches meet in front of the pericardial region, and, fusing together, form the posterior or lower margin of the aperture; simultaneously the lateral boundaries of the space are still further completed by the forward growth of a nodular projection, the **maxillary process,** from the upper end of each mandibular arch. About the fifteenth day the bucco-pharyngeal membrane disappears, and the stomatodæal space and pharynx are thenceforth continuous. No trace of the bucco-pharyngeal membrane is recognisable in the adult, but its position may be represented by an imaginary plane extending from the anterior part of the basi-sphenoid above to the base of the alveolar process of the lower jaw, on its lingual surface, below.

Whilst the boundaries of the stomatodæal space are being defined, two oval depressions, lined with thickened epithelium, appear in its upper boundary on the lower and anterior surfaces of the fronto-nasal process; these are the **olfactory pits** or depressions. A portion of the epithelium of their walls is separated off and takes part in the formation of the olfactory bulbs, whilst the remainder is transformed into the olfactory epithelium, from which the olfactory nerve-fibres grow inwards to the olfactory bulbs. As the olfactory pits deepen they grow backwards into the roof of the stomatodæal space, and at the same time they separate the lower portion

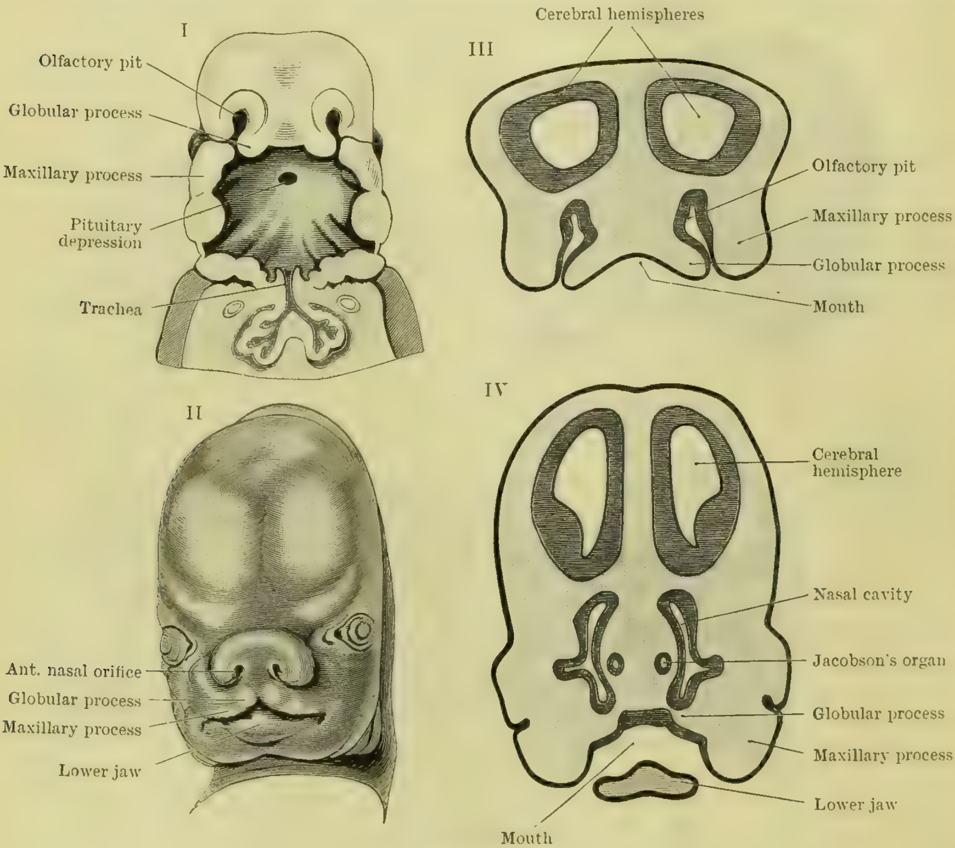


FIG. 30.

I. Portion of the head and neck of a human embryo 32 days old. The floor of the mouth and pharynx and the ventral part of the anterior portion of the body have been removed. By the approximation of the globular and maxillary processes the boundaries of the anterior nares are almost complete, but the olfactory pits still open in the whole of their lengths into the roof of the mouth (from His).
II. Transverse section of the head of an embryo, showing the close apposition of the globular and maxillary processes.
III. Head of human embryo about 2 months old, showing the union of the globular processes and their fusion with the maxillary processes. The anterior nasal apertures are now completely defined (from His).
IV. Transverse section of the head of an embryo, showing the fusion of the maxillary processes with the globular processes, and the separation anteriorly of the nose from the mouth.

of the fronto-nasal process into three parts, constituting a median and two lateral nasal processes. At each lateral angle of the median nasal process a spheroidal elevation, the **globular process**, appears. The part of the median nasal process which intervenes between the two globular processes is divided into two areas, an upper triangular and a lower quadrilateral, by the appearance of a tranverse ridge, which is afterwards moulded into the tip of the nose. The upper triangular area becomes the dorsum of the nose, and the lower quadrilateral area forms the columella, *i.e.* the lower and anterior part of the septum between the anterior nasal apertures. The globular processes are utilised in the formation of the **philtrum** or middle part of the upper lip, and the lateral nasal processes form the alæ of the nose or lateral boundaries of the anterior nasal apertures. As the olfactory pits

deepen and grow backwards into the roof of the stomatodæum the maxillary processes grow forwards from the lateral boundaries of that space, that is from the upper ends of the mandibular arches, and pass beneath the eyes, which now form distinct prominences on the sides of the head. The upper borders of the maxillary processes come into contact with the lateral nasal processes from which they are temporarily separated by grooves, the **oculo-nasal sulci.** These latter pass from the depressions round the eyeballs, the rudimentary conjunctival sacs, to the margins of the nasal pits. The anterior extremities of the maxillary processes impinge upon the globular processes, and ultimately their upper borders and anterior extremities fuse with the lateral nasal and globular processes completing the posterior boundaries of the anterior nasal orifices, and the lateral parts of the primitive upper lip. At the same time the oculo-nasal sulci are converted into the lachrymal sacs and the nasal ducts, which henceforth constitute the channels of communication between the conjunctival sacs and the nose.

The result of the ingrowth of the maxillary processes and their fusion with the lateral nasal and globular processes is the division of the large orifice which led into the stomatodæal space into three parts—a large lower, and two smaller upper apertures. The lower opening is the aperture of the mouth; it is bounded below by the

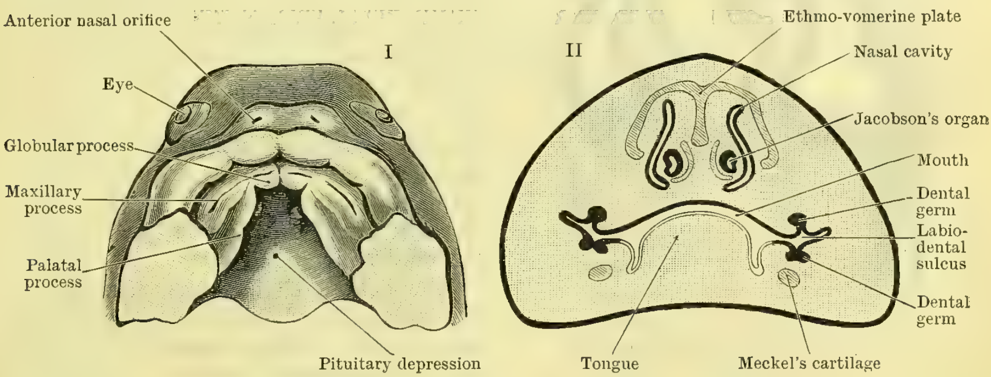


Fig. 31.

I. Portion of the head of a human embryo about $2\frac{1}{2}$ months old (His). The lips are separated from the gums, and the line of the common dental germ is visible in the latter. The palatal processes are growing inwards from the maxillary processes.

II. Transverse section of the head of an embryo after the fusion of the palatal processes of the maxillary processes with the nasal septum, which grows backwards from the fused globular processes.

united mandibular arches, and above by the fused mesial nasal, and maxillary processes. The smaller upper openings are the anterior nares, which on their first formation are merely foramina of communication between the exterior and the upper part of the stomatodæal space; the latter is not yet separated into nasal and oral chambers.

Formation of the Palate and the Separation of the Nasal and Buccal Cavities.—This separation is effected by the formation of the palate, which is developed to a slight extent by the backward growth of the globular processes along the roof of the space as a pair of ridges, termed the **nasal laminæ**, which fuse together to form a small anterior portion of the palate, viz. the intermaxillary process, in which the intermaxillary parts of the superior maxillæ are formed. The remaining and greater part of the palate is formed by two ledge-like ingrowths, one from the inner surface of each maxillary process, which meet and fuse anteriorly with the intermaxillary process, and behind this with each other. In these projections the palatal processes of the superior maxillæ and the horizontal plates of the palate bones are formed, and by their fusion the upper part of the stomatodæal space is separated off from the remainder as a common nasal chamber which communicates in front with the exterior by the anterior narial orifices, and behind with the pharyngeal portion of the fore-gut by the choanal apertures or posterior nares. The lower part of the stomatodæal space and the front part of the fore-gut together form the mouth or buccal cavity; this opens anteriorly by a transverse

aperture, the boundaries of which have already been described, and posteriorly it is in direct continuity with the pharynx.

The division of the common nasal chamber into two parts commences before its separation from the mouth is completed, and it is brought about by the development of a septum which is continuous anteriorly with the fused nasal laminæ, and which grows downwards and backwards from the mesial part of the under aspect of the fronto-nasal process. This septum fuses below with the conjoined margins of the palatal ledges of the maxillary processes, and a vertical plate of cartilage soon develops in its interior, which is continuous above with the cartilaginous base of the cranium (basi-cranial axis). A portion of this septal cartilage remains in the adult as the septal cartilage of the nose, and the remainder is more or less completely replaced by the vertical plate of the ethmoid bone and by the vomer. The lateral wall of each nasal chamber is formed, in the lower part of its extent, by the maxillary process of the mandibular arch, in which the superior maxillary, malar, and palate bones, and possibly the internal pterygoid plate, are developed, and in the upper part by the outer boundary of the original nasal pit, which now forms only the upper part of the nasal cavity. In this upper section of the outer wall an outgrowth of the basi-cranial axis projects downwards, and is developed into the lateral mass of the ethmoid bone; probably it also takes part in the formation of the inferior turbinal bone.

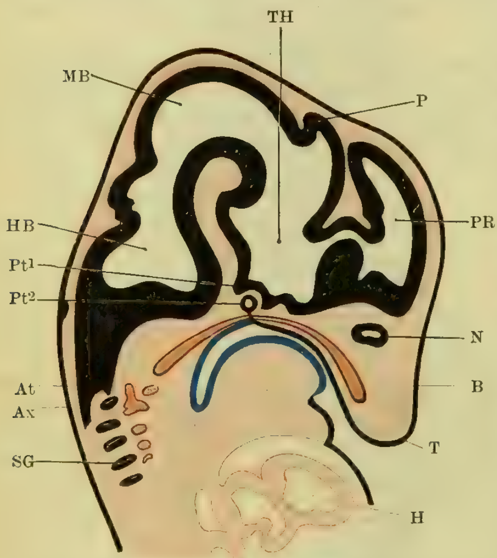


Fig. 32.—Vertical Section through Head of Rat Embryo.

Showing the formation of the two parts of the pituitary body (diagrammatic).

(Ectoderm is represented in black, entoderm in blue, and mesoderm in red.)

At. Atlas.
Ax. Axis.
B. Cartilaginous basi-cranial axis.
H. Heart.
HB. Hind-brain.
MB. Mid-brain.
N. Part of nasal cavity.
P. Pineal body.
PR. Cerebral hemisphere.
Pt[1]. Cerebral part of pituitary body.
Pt[2]. Buccal part of pituitary body.
SG. Spinal ganglion.
T. Tongue.
Th. Thalamencephalon.

The fusion of the three segments of the palate commences anteriorly at the eighth week by the union of the maxillary and globular processes; it passes backwards and is completed by the fusion of the posterior parts of the palatal ledges of the maxillary processes, about the tenth week. To the non-completion of this fusion the various cases of hare-lip and cleft palate are due.

The Organ of Jacobson.—The organs of Jacobson are rudimentary structures in man. They lie in the lower and anterior part of the nasal septum, one upon each side. They are developed as small diverticula which grow backwards and upwards in the substance of the septum, and their points of commencement are situated immediately above the intermaxillary segment of the palate. Each diverticulum is partially surrounded, on its inner side, by a cartilaginous capsule, it ends blindly behind, and it opens anteriorly close to the floor of the nose in the region of Stenson's foramen—a small aperture left between the premaxillary and maxillary sections of the bony palate.

The Pituitary Body.—The pituitary body is formed partly from the floor of the first primary cerebral vesicle, and partly from the roof of the stomatodæal space. The stomatodæal portion appears as a small pouch, Rathke's pouch, which grows dorsally into the base of the head immediately in front of the dorsal end of the bucco-pharyngeal membrane and the anterior end of the notochord and behind the fore-brain. It is lined by ectoderm, and soon becomes a conical vesicle which lies beneath the base of the fore-brain. Its orifice of communication with the stomatodæal space is gradually constricted until the lumen disappears, and then for a time the vesicle is connected with the surface by a solid cord of ectodermal

cells. This also disappears, and the vesicle is embedded in the base of the head in a region above and between those parts of the basal axis which afterwards are transformed into the basi- and pre-sphenoid elements of the sphenoid bone.

During the period of its formation and separation the ingrowth from the stomatodæum comes into relation posteriorly with a small diverticulum from the floor of the fore-brain, which dilates at its lower end to form the posterior or cerebral lobe of the pituitary body, whilst its upper part remains as the infundibulum, the connecting stalk between the pituitary body and the floor of the third ventricle of the brain. The anterior or stomatodæal lobe of the pituitary body is much larger than the posterior lobe, which it surrounds and conceals both in front and at the sides.

It is evident that in the early stages the pituitary body consists of two ectodermal vesicles, the cavity of the posterior vesicle is continuous with the cerebral tube, and that of the anterior vesicle with the cavity of the primitive mouth. The cavity of the posterior vesicle is generally obliterated, and though nervous structures are for a time developed in its walls they entirely disappear in man and are replaced by vascular connective tissue. Occasionally a small part of the cavity remains as a minute vesicle lined with columnar ciliated epithelium.

The cavity of the anterior vesicle persists, it sends out numerous diverticula, and is gradually converted into a number of tubular spaces, lined with cubical or columnar cells, united together by vascular connective tissue which has grown amidst the tubules from the surrounding mesoderm.

THE EXTERNAL EAR, THE TYMPANIC CAVITY, AND THE EUSTACHIAN TUBE.

The external ear, the tympanic cavity, and the Eustachian tube are all developed from the first visceral cleft and its boundaries. The cleft lies between the mandibular (first) and the hyoid (second) visceral arch in the side wall of the pharyngeal portion of the fore-gut, and, before a neck is developed, it extends from just beneath the otic vesicle, which lies at the side of the hind-brain, above, to the pericardial region below. The membrane which lies at the bottom of the cleft consists in the early stages of ectoderm and entoderm, but in a short time a thin layer of mesoderm grows between the two primary layers, and the trilaminar septum is ultimately converted into the tympanic membrane which separates the external from the middle ear.

The differentiation of the outer part of the cleft is initiated by the appearance of six tubercles round its margins, which are afterwards transformed into the several parts of the pinna.

Two tubercles are formed anteriorly on the mandibular arch, one at the upper end of the cleft and three posteriorly on the hyoid arch. The two tubercles on the mandibular arch are a small lower, the **tuberculum tragicum,** and a larger upper, the **tuberculum anterius helicis.** The tubercle at the upper end of the cleft is the **tuberculum**

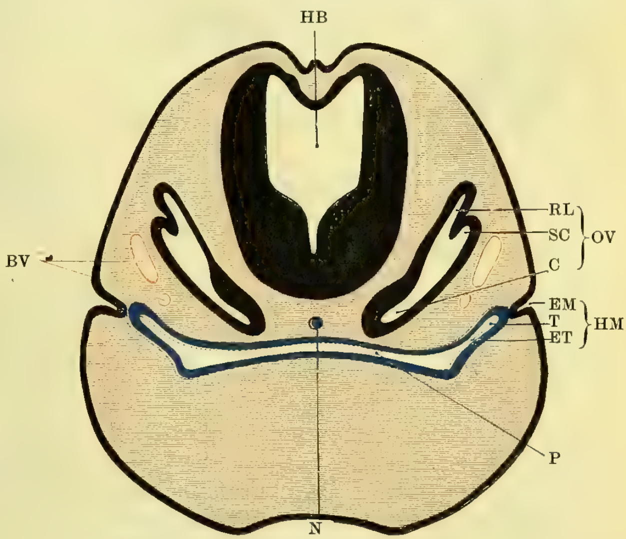


Fig. 33.—Transverse Section through the Head of a Rat Embryo.

Showing the rudiments of the three parts of the ear and their relation to the hyo-mandibular cleft.

BV.	Blood-vessels.	N.	Notochord.
C.	Cochlea.	OV.	Otic vesicle.
EM.	Ext. auditory meatus.	P.	Pharynx.
ET.	Eustachian tube.	RL.	Recessus labyrinthii.
HB.	Hind-brain.	SC.	Semicircular canal.
HM.	Hyo-mandibular cleft.	T.	Tympanum.

intermedium helicis. The upper tubercle on the hyoid arch is the **tuberculum anthelicis,** the middle is the **tuberculum antitragicum,** and the lowest is the **tuberculum lobulare.** Shortly after the appearance of the tubercles a process, the **caudal process,** grows backwards and downwards, from the posterior part of the tuberculum intermedium helicis, behind the tuberculum anthelicis and the tuberculum antitragicum to the tuberculum lobulare, with which it fuses. The tuberculum tragicum remains more or less distinct, and it forms the prominence called the tragus which lies in front of the concha and external auditory meatus.

The two tubercles of the helix and the caudal process unite to form the helix or marginal portion of the pinna; this terminates below in the lobule which is developed from the tuberculum lobulare. The tuberculum anthelicis and the tuberculum antitragicum are the rudiments respectively of the antihelix and the antitragus, and the latter unites below the lower part of the cleft with the rudiment of the tragus, forming the lower boundary of the outer part of the external meatus. It should be noted that in the early stages the tuberculum anterius helicis lies in front of the outer part of the first visceral cleft, but it does not retain this position in the later stages during which the cleft is relatively reduced in size, and when development is completed and the outer part of the cleft is transformed into the external auditory meatus the commencement of the helix, which is developed from the tuberculum anterius helicis, is situated just above the outer extremity of the external meatus.

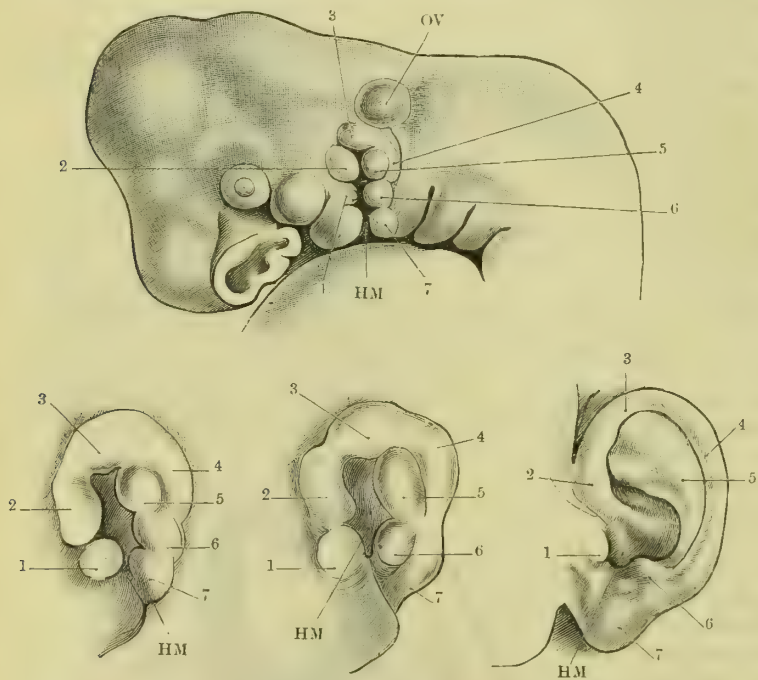


FIG. 34.—FIGURES, MODIFIED FROM HIS, ILLUSTRATING THE FORMATION OF THE PINNA.

1. Tuberculum tragicum = Tragus.
2. ,, anterius helicis } Helix.
3. ,, intermedium helicis } Helix.
4. Cauda helicis } Helix.
5. Tuberculum anthelicis = Antihelix.
6. Tuberculum antitragicum = Antitragus.
7. Tuberculum lobulare = Lobule.

HM. Hyo-mandibular cleft.
OV. Otic vesicle.

The outer part of the cleft is moulded into the external auditory passage. It remains relatively shallow and devoid of bony boundaries till after birth, but in the subcutaneous tissue round the lower margin of the tympanic membrane an incomplete ring of bone is formed during the third month, and at an earlier period, above the upper part of that membrane, the rudiment of the squamous part of the temporal bone appears. To the outer side of the tympanic ring in the subcutaneous tissue of the pinna and the outer part of the external auditory passage three pieces of cartilage appear, and they afterwards join to form the cartilage of the pinna and the external auditory meatus.

After birth the external meatus is deepened, by the outgrowth of the tympanic ring below and of the squamous part of the temporal bone above, together with a coincident increase of the outer part of the canal.

The **tympanic cavity** and the **Eustachian tube** are both formed from the inner part of the first visceral cleft, and consequently they are both lined by entoderm.

The tympanic cavity is developed from the dorsal or upper end of this portion of the cleft, and it is prolonged upwards on the outer side of the otic vesicle which simultaneously descends in the tissues of the head. Thus the upper end of the inner portion of the cleft, which is somewhat dilated, comes to lie between the otic vesicle, which is developed into the internal ear, on the inner side, and the tympanic membrane which separates it from the external auditory meatus on the outer side, and it remains in the adult as a laterally compressed space, the tympanic cavity, which is continuous through the Eustachian tube with the upper part of the pharynx. In the mesoderm round the inner, upper, and back part of the cavity the petrous part of the temporal bone is developed and ossified, and in the lower and anterior part the tympanic ossification extends outwards during the formation of the tympanic plate.

The upper part of the tympanic space is prolonged backwards between the ossifying petrous and squamous parts of the temporal bone, where it forms a recess known in the adult as the mastoid antrum, from which at a later period diverticula are projected into the mastoid portion of the temporal bone, forming the mastoid air cells.

The lower portion of the inner part of the cleft is moved obliquely forwards. As development proceeds it is contracted and carried downwards and forwards in front of the developing otic vesicle. It is the rudiment of the Eustachian tube, and, as the septum which separates the nasal chambers from the mouth is formed, its lower end attains a position just behind and at the side of the posterior narial orifice in the upper and lateral part of the pharynx. Apparently, therefore, the lower end of the Eustachian tube has a much higher position than that originally occupied by the lower end of the cleft from which it is formed, for it will be remembered that the lower end of the first visceral cleft is situated, in the early stages, at the side of the tuberculum impar from which the anterior two-thirds of the tongue is formed. This alteration in relative position is due, however, not to elevation of the lower end of the first visceral cleft during its transformation into the Eustachian passage, but to the enormous downgrowth of the mandibular arches, which carry with them the tongue, as they enlarge to form the lower jaw.

THE HIND-GUT, THE ANAL PASSAGE, AND THE POST-ANAL OR TAIL GUT.

By the formation of the mouth the primitive alimentary canal opens anteriorly; it remains closed posteriorly until a later date, when the anal passage and orifice are developed.

The posterior end of the hind-gut which is enclosed in the tail-fold is termed the cloaca. The **cloaca** is dilated, and, assuming a conical form, receives the terminations of the genito-urinary ducts. It is bounded postero-inferiorly by the **cloacal membrane** which extends from the root of the tail to the body stalk by which the embryo is attached to the chorion. The cloacal membrane is modified from the posterior part of the primitive streak; this remains on the surface of the body after the anterior part has been separated and enclosed during the completion of the posterior part of the neural canal, and it forms a septum between the cavity of the cloaca and the exterior. It consists at first of ectoderm and entoderm alone, and it is only at its lower and anterior part that it is subsequently invaded to a slight extent by mesoderm.

During the second month of intrauterine life the cloaca is divided into a ventral or genito-urinary, and a dorsal or rectal section, by the formation and fusion of lateral folds, which gradually unite, from before backwards, till finally the posterior end of the septum approaches and fuses with the cloacal membrane, and the rectum is separated from the genito-urinary chamber. Before this separation is completed an eminence appears in the region of the anterior part of the cloacal membrane at the junction of the ventral surface with the posterior extremity of the body, *i.e.* in that part which afterwards becomes the region of the symphysis pubis. This eminence is the **genital eminence**, and from it are formed the penis in the male and the clitoris in the female. The genital eminence is

surrounded by an oval fold of skin, the **genital fold**, which extends from the front of the eminence to the root of the tail and encloses a shallow fossa, the **cloacal fossa**, at the bottom of which is the **cloacal membrane.** The posterior part of the cloacal fossa is afterwards separated from the anterior part by a transverse fold, the **perineal fold,** which crosses the external surface of the cloacal membrane in a position which corresponds internally with that occupied by the lower end of the septum separating the genito-urinary from the rectal portions of the cloaca. The posterior part of the cloacal fossa, behind the transverse fold, is the proctodæal depression or **proctodæum**; at first its long axis lies transversely, afterwards it assumes a triangular and then a circular form, the sphincter ani muscle develops in its walls, and it is transformed into the greater part, if not the whole, of the anal canal of the adult. It is separated from the rectum by the posterior part of the cloacal membrane, but when that disappears, at a date which has not yet been definitely ascertained, but probably about the third month, the anal passage forms the canal by which the rectum communicates with the exterior of the body.

The orifices of the alimentary canal are thus completed.

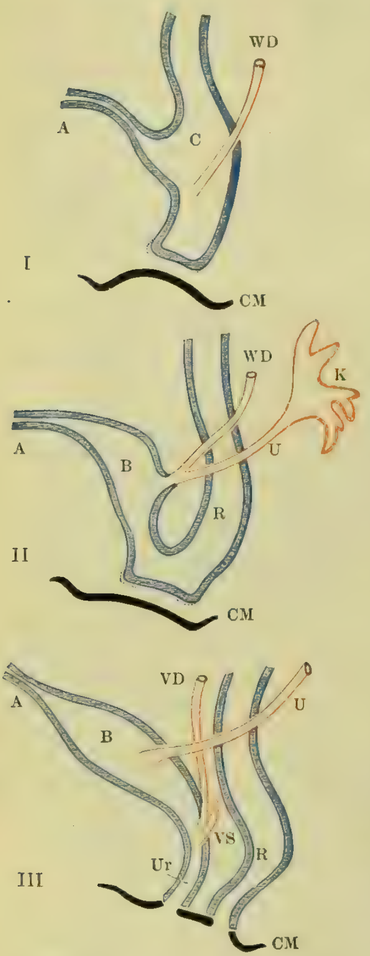


FIG. 35.—DIAGRAMS showing the separation of the cloacal part of the hind-gut into genito-urinary tract and rectum.

A. Allantoic stalk.	U. Ureter.
B. Bladder.	Ur. Urethra.
C. Cloaca.	VD. Vas deferens.
CM. Cloacal membrane.	VS. Vesicula seminalis.
K. Kidney.	WD. Wolffian duct.
R. Rectum.	

The Post-anal or Tail Gut.—When the hind-gut is first enclosed there is no tail, but a rudimentary tail is subsequently developed as an outgrowth from the dorsal end of the tail-fold, *i.e.* from the posterior extremity of the body of the embryo. As the tail is formed, a narrow tube, which communicates in front with the hind-gut, is developed within it. This is called the post-anal or tail gut. As a rule it only exists for a short time, disappearing from before backwards about the period when cartilage begins to be formed in the body and limbs, and before the cloaca is divided into its rectal and genito-urinary portions. In the few cases in which it persists it retains its continuity with the rectum, which is formed from the dorsal part of the cloaca.

It appears in the human subject when the embryo is 3 mm. long, and the rudimentary tail is just visible as a small nodule. When the embryo attains the length of 4·8 mm. the anterior part of the tail-gut begins to degenerate, its cavity disappears, and it is converted into a solid cord of cells which is still attached in front to the hind-gut. In embryos 11·5 mm. long, when the tail has been enclosed in the posterior part of the body, the connexion of the tail-gut with the hind-gut is lost, and the tail-gut is represented by a small vesicle with a short cord of degenerating cells attached to its anterior part.

In larger embryos the tail-gut entirely disappears. When, as in the human subject, the rudimentary tail is eventually embedded in the posterior end of the body, any rudiments of the tail-gut which persist will be found in this situation; it is stated that such rudiments occasionally develop into tumour formations. In mammals with free tails, rudiments of the tail-gut may be met with in any part of the tail, and apparently the anterior portion occasionally persists and maintains its connexion with the rectum, from which it extends backwards as a narrow and blind diverticulum.

THE LIMBS.

Though the body of the embryo begins to assume definite form as soon as it is folded and nipped off from the rest of the ovum, it does not present any distinguishable human characteristics until the anterior and posterior limbs are formed. There are no traces of these before the third week of intrauterine life when two longitudinal ridges, the **Wolffian ridges**, are developed, one on each lateral surface of the body, just external to the outer margins of the protovertebral somites, and opposite the line of the intermediate cell mass. The rudiments of the fore and hind limbs are discernible, almost from the first, as slight prominences of the Wolffian ridges, and in the fourth week they project as bud-like outgrowths in the thoracic and pelvic regions respectively. The development of the fore-limb or arm is throughout slightly in advance of that of the hind-limb or leg. At the fourth week each limb-bud is a flattened semi-lunar projection, as long as it is broad, with dorsal and ventral surfaces and anterior or preaxial, and posterior or postaxial borders. As growth proceeds, the elongating limb-buds are bent ventrally, and in the fifth week two transverse furrows, on the ventral aspect of each, indicate the positions of the joints and the division of each limb into three segments—distal, middle, and proximal—representing the hand, forearm, and arm in the upper limb, and the foot, leg, and thigh in the lower limb. The terminal or distal segments are broad flat plates with rounded margins, but each is soon divided into a somewhat enlarged basal part, and a thinner and more flattened marginal part. It is where these two parts are continuous that the rudiments of the digits appear. They become distinguishable about the end of the fifth week as small lobes which gradually extend outwards. In the fore-limb the fingers project beyond the margin of the hand-segments in the sixth week, but the toes do not reach the margins of the foot till the early part of the seventh week. The nails appear at the third month, and reach the ends of the digits at the sixth month.

In the primary position of the limbs the elbow and the knee appear alike to be directed outwards, but this is soon altered. At the end of the sixth week each limb undergoes a partial rotation, the direction of which is different in the fore and hind limbs respectively. In the former the elbow is turned backwards, the ventral surface therefore becomes anterior, and the preaxial (thumb) margin is directed outwards; in the hind-limb the knee is turned forwards and the ventral surface of the limb becomes posterior, whilst the preaxial (great toe) margin is directed inwards; thus in the adult the anterior surface and outer border of the upper extremity correspond with the posterior surface and inner border of the lower extremity, whilst obviously the posterior surface and inner border of the former are homologous with the anterior surface and outer border of the latter.

Each limb-bud may be regarded as an extension from a definite number of the segments of the body; it contains a core of mesoderm, and the anterior or ventral primary divisions of the corresponding spinal nerve segments are apparently prolonged into it.

The central part of the mesoderm, except in the regions of the joints where cavities appear, is condensed and then converted first into cartilage and afterwards into bone. The proximal part of the bony skeleton of each limb, the limb girdle, is not however developed in the limb-bud, but in the body wall at its base. The more superficially situated mesoderm is transformed into muscles and subcutaneous tissues, the extensor muscles appearing on the dorsal and the flexor muscles on the ventral aspect.

As the nerve trunks pass into the free portion of the limb they bifurcate, the branches passing respectively to the dorsal or extensor aspect of the limb, and to its ventral or flexor aspect.

Apparently in mammals the whole of the mesodermal core of each limb-bud is formed from the somatic mesoderm of the lateral plates. If this is the case the muscles of the limbs differ in origin from those of the back, for the latter are developed from the muscle-plates of the protovertebral somites. In lower vertebrates (cartilaginous fishes) buds are given off to the limbs from the muscle-plates

and cutaneous lamellæ in the thoracic and pelvic regions, and as the muscle-plates pass downwards in the somatopleure towards the ventral aspect of the body, these buds grow outwards into the limb-rudiments and develop into the muscles of the limbs. Presumably this is the more primitive arrangement, and that met with in man and other mammals is secondary, and it is stated that although no distinct buds from the muscle-plates pass into the limbs of mammals nevertheless the limb-muscles are formed by cells, proliferated from the muscle-plates, which have migrated into the somatopleural mesoderm of the limbs.

THE NUTRITION AND PROTECTION OF THE EMBRYO DURING ITS INTRAUTERINE EXISTENCE.

The impregnated ovum during its passage down the Fallopian tube, and for a brief period also after it enters the uterus, lives either on the yolk granules (deutoplasm) embedded in its own cytoplasm or upon material absorbed from the fluids by which it is surrounded. The human ovum is very small, and consequently it is almost from the first dependent for its nutrition upon sources of supply outside itself. The urgent necessity for adequate arrangements whereby this may be effected leads to that early establishment of an intimate vascular connexion between the embryo and the mother which is so characteristic a feature in the development of the human ovum. At the end of the second week, after fertilisation of the ovum, the embryo is separated by a slight constriction from the rest of the blastodermic vesicle, and already a primitive heart and rudimentary blood-vessels are distinguishable.

The development of the vascular system, and the establishment of the fœtal circulation, however, cannot well be understood until the formation and structural features of the group of closely associated extra-embryonic organs or appendages have been considered.

This group includes the yolk-sac, the chorion, the amnion, the allantois, and the placenta.

THE FŒTAL MEMBRANES AND APPENDAGES.

The Yolk-Sac or Umbilical Vesicle.—That portion of the blastodermic cavity and its wall which is not included in the body of the embryo to form the primitive alimentary canal constitutes the umbilical vesicle or yolk-sac. Its walls, like its cavity, are continuous with the corresponding parts of the intestine, and their structural features are identical, there being an inner layer of entodermal cells and an outer layer which is formed by the splanchnic layer of the mesoderm.

In the human embryo the yolk-sac is a small flask-like body, suspended from the ventral wall of the alimentary canal by a hollow stalk, the **vitello-intestinal duct,** which passes through the umbilical orifice. It lies in the extra-embryonic continuation of the body-cavity (cœlom), and is filled with fluid. Possibly the contents of the yolk-sac are utilised in the nutrition of the embryo in its earliest stages, and the first rudiments of the blood-vascular system, viz. blood corpuscles and vessels, appear in its walls. In the human embryo, however, it is of little nutritional importance; it soon atrophies and almost entirely disappears, but leaves traces of its existence in the umbilical cord.

The Amnion.—The amnion is a protective sac which surrounds the embryo. It is formed, after the development of the cœlom, from the amniotic area of the blastoderm, and its wall is continuous, at the margins of the umbilical orifice, with the body-wall of the embryo. Both walls consist of a layer of ectoderm and a layer of somatic mesoderm, but whilst in the body-wall the ectoderm is external and the mesoderm internal, the relative positions of the layers are reversed in the amnion, the mesoderm being external and the ectoderm internal.

The cavity enclosed between the amnion and the embryo, the **amniotic cavity,** is filled with fluid, the **amniotic fluid,** in which the embryo floats. The amniotic cavity is quite shut off for some time from all the neighbouring spaces, but after

the disappearance of the bucco-pharyngeal and cloacal membranes it communicates, both anteriorly and posteriorly, with the alimentary canal of the embryo.

The development of the amnion in higher mammals is closely associated with the attachment of the ovum to the uterine wall and with the subsequent formation of the placenta.

Before the cœlom is formed, the ectoderm in the chorionic area becomes attached to the uterine tissues by small villous outgrowths which invade the uterine mucous membrane. This attachment is most complete in the placental region, that is, around the margins of the amniotic area. As the embryo is folded off from the blastoderm and the cœlom develops, both the embryo and the amniotic area remain quite free from the uterine tissues, indeed, it may be said that, at this period, the embryo is suspended from the margins of the placental area by the amniotic membrane.

As development proceeds the amniotic area increases in extent by interstitial growth, and thereupon the embryo, the membrane which suspends it being relaxed, sinks more and more into the interior of the ovum, or, to be more precise, into the cœlomic space, which, in the meantime, has considerably increased. At the same time the growth of the placental area causes all parts of its inner margin to converge, and as the inner margins of the placental area are continuous with the outer margins of the amniotic membrane, the amnion is gradually carried over the dorsal surface of the embryo till its margins meet and fuse. After the fusion of its margins the amnion separates entirely from the chorionic area, henceforth known as the chorion, and forms a closed sac which completely surrounds the embryo.

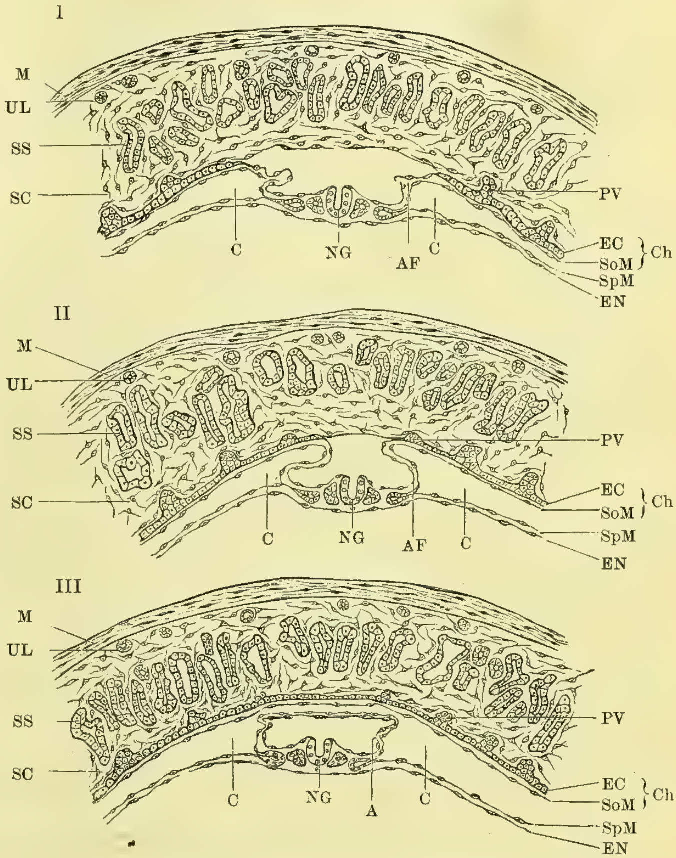


Fig. 36.—Transverse Sections of the Uterus and Developing Ovum of a Ferret.

Showing the formation and closure of the amnion folds, the completion of the amnion, and the coincident ingrowth of the inner margins of the placental area of the blastoderm.

A. Amnion.	EN. Entoderm.	SC. Stratum compactum.
AF. Amnion fold.	M. Muscular wall of uterus.	SS. Stratum spongiosum.
C. Cœlom.		SoM. Somatic mesoderm.
Ch. Chorion.	NG. Neural groove.	SpM. Splanchnic mesoderm.
EC. Ectoderm.	PV. Placental villus.	UL. Unchanged layer of uterine mucosa.

On reference to Figs. 19 and 25 it will be seen that as the wall of the blastodermic vesicle is carried inwards over the dorsal surface of the embryo it is folded; the outer part of the fold consists of the chorionic portion, and the inner part of the amniotic portion of the blastoderm. The fold is called the **amnion fold**; it is quite continuous round the whole margin of the embryo, but some parts of it are more advanced than others, or in other words the convergence of the inner margin of the placental area of the blastoderm over the dorsal surface of the embryo does not take place at the same rate or to the same extent in all parts. For convenience

of description it is usual to divide the amnion fold into four parts, the cephalic, the caudal, and the two lateral amnion folds; these, however, are all continuous with one another.

The inner part of the fold, which is formed from the amniotic area, is termed the **true amnion**, and the outer part, formed from the chorionic area, the **false amnion**. The latter term is, however, synonymous with chorion, and as it is misleading, it should be avoided.

As the amnion is formed from the amniotic area of the blastoderm after the extension of the cœlom, it must consist, as previously mentioned, of ectoderm and somatic mesoderm, and as the surface of the amniotic area is reversed during the formation of the amnion folds, it is obvious that in the fully-formed amnion the ectodermal layer is internal and the somatic mesoderm external.

After the amnion is completed its cavity is distended with fluid. As it expands it gradually obliterates the extra-embryonic part of the cœlomic cavity, and finally its outer surface, of somatic mesoderm, comes into contact and fuses with the somatic mesoderm on the inner surface of the chorion. At this period the cavities in the ovum are the amniotic cavity, the remains of the yolk-sac, and those portions of the original blastodermic and cœlomic spaces which have been included in the embryo.

In the human ovum, when the amnion folds unite and the true amnion separates from the chorion, the embryo and its enclosing amnion would be free within the cavity of the chorion, or extra-embryonic cœlom, were it not that a very short cord of somatic mesoderm and ectoderm, the body-stalk, connects the posterior end of the embryo with the somatic mesoderm on the inner surface of the chorion.

The Body-Stalk.—To thoroughly understand how this union is effected in the human ovum, and to comprehend the nature of the body-stalk, it is necessary to refer to some striking peculiarities which are to be observed in the earlier stages in the development of the human embryo. When segmentation is completed, and the morula is converted into a blastula by the appearance of a cavity in its interior, the human ovum consists of an outer layer, the ectoderm, and an inner cell mass (Figs. 10 and 37). The latter, however, which is attached to a small area of the ectoderm, does not, as in many mammals, extend itself by migration round the inner surface of that layer, and so transform the unilaminar into a bilaminar blastoderm and convert the cavity of the blastula into the blastodermic cavity. The sequence of events is different: a cavity or space appears in the inner cell mass itself (Figs. 38, 39, and 41), and this expanding rapidly, is ultimately converted into the yolk-sac and the alimentary canal of the embryo; it corresponds, therefore, with the blastodermic cavity of other mammals.

Thus the entoderm, though derived from the inner cell-mass, never lines the inner surface of the ectoderm except in the embryonic area, for soon after the appearance of the cavity of the inner cell-mass the mesoderm grows rapidly from the primitive streak and extends, not in a single layer, as in the majority of mammals, but as two layers, one over the outer surface of the entoderm, the splanchnic layer, and the other, the somatic layer, over the inner surface of the ectoderm. The cavity of the blastula is thus ultimately enclosed between the somatic and splanchnic layers of the mesoderm, and so becomes converted into the cœlomic space (Fig. 39).

As the mesoderm extends, the several areas of the blastoderm are differentiated as in other mammals, but the embryonic and amniotic areas remain of relatively small size. The separation of the amnion from the chorion is effected at a very early period, before the folding off of the embryo has commenced, but the somatic mesoderm growing from the posterior end of the embryonic area still retains its connexion with the similar layer on the inner surface of the chorion, and it forms a short, and for a time a broad stalk which unites the embryo, and consequently the amnion and the blastodermic cavity, with which the embryo is connected, to the chorion (Fig. 39). In addition to forming a bond of union between the embryo and the chorion the mesodermal stalk conducts blood-vessels from the embryo to the chorion, and more especially to its placental part.

At an early period a pouch-like diverticulum projects from the posterior part of the entodermal sac. This is the **allantoic diverticulum**; it lies beneath the

posterior part of the embryonic area, and the area is curved upon itself so that its convexity looks towards the entodermal sac, and its concavity towards the amnion.

After the embryonic area has increased in extent, and when the folding off of the embryo has commenced, the anterior end of the area and the posterior end of the primitive streak remain relatively stationary as in other mammals, the cephalic and caudal folds appear, and the curvature of the greater part of the area is reversed, but the most posterior part retains its original position, lying for a time parallel with the caudal fold; afterwards, however, it assumes a more horizontal position. This posterior section of the embryonic area contains the diverticular process of the entodermal sac which is called the allantois; it also contains the blood-vessels, allantoic arteries and veins, which pass between the embryo and the placenta. It is in relation at first with the amnion, it appears to be entirely behind the embryo, and it is called the "body-stalk." At a later period, when the stalk of mesoderm—the allantoic stalk—which connects it with the inner surface of the chorion is elongated, this part of the embryonic area is reversed in position, its anterior end is carried forwards till it forms the posterior boundary of the umbilical orifice, and it forms the ventral wall of the body from the umbilical to the genital region.

The Allantois.—The allantois plays an important part in the formation of the placenta. It consists of two portions, an entodermic diverticulum from the ventral wall of the cloacal part of the hind-gut, and a mesodermal covering. The entodermic diverticulum appears in the human subject, before the hind-gut is defined, as a hollow blind protrusion from the blastodermic cavity; it extends behind the primitive streak into the mesoderm of the body-stalk, but as the folding off of the embryo proceeds and the body-stalk is carried forward into the ventral wall of the embryo, the position of the diverticulum is altered, and ultimately, when the folding off is completed, it springs from the ventral part of the cloaca, runs forward to the umbilical orifice and passing through it, projects for a short distance still invested with the mesodermal covering primarily obtained from the body-stalk. The ventral part of the cloaca is afterwards converted into the bladder, while the rectum is formed from the dorsal part.

The mesodermal sheath which surrounds the entodermic diverticulum extends beyond it to the inner surface of the chorion; the part which extends beyond the diverticulum is at first extremely short, indeed it is only recognisable as a layer of mesoderm uniting the body-stalk and chorion, but as development proceeds and the body-stalk is absorbed into the embryo it is elongated, and it forms the **allantoic stalk** by which the embryo retains its connexion with the chorion, and along which pass the allantoic or umbilical arteries to, and the corresponding veins from, the chorionic villi.

After the separation of the cloaca into bladder and rectum, that portion of the allantois which lies in the body of the embryo, between the apex of the bladder and the umbilical orifice, is gradually converted into a fibrous cord, the **urachus**. The entodermal diverticulum disappears, and after birth, when the placental circulation ceases, the umbilical arteries are transformed into fine fibrous strands. The remainder of the allantois which lies outside the body of the embryo, and which takes part in the formation of the umbilical cord and placenta, is separated from the embryo at birth.

The Umbilical Cord.—The umbilical cord is essentially a mesodermal structure which connects the embryo with the placenta, serving as a passage for the allantoic vessels to and from the fœtal portion of the latter organ. It replaces the body-stalk and the allantoic stalk, which were earlier provisions for the same purpose, and it is formed by the fusion of the allantoic stalk with part of the vitello-intestinal duct and the remains of the yolk-sac.

The vitello-intestinal duct is at first a relatively wide channel which connects the primitive gut with the yolk-sac; and it passes through the umbilical orifice. In later stages, as the body-stalk is swung round into the ventral wall of the body, the allantoic stalk, which projects from the end of the body-stalk, is brought into close relation with the distal end of the vitello-intestinal duct and the remains of the yolk-sac; the mesodermal constituents of the three structures then fuse

together, and the whole is surrounded by the expanding amnion. In this way the umbilical cord is formed. It includes therefore the allantoic stalk and its blood-vessels, together with the remains of the yolk-sac and its stalk, the vitello-intestinal duct, all of which are invested and bound together by the amnion.

The mesodermal core of the cord forms a fibro-mucoid tissue known as "Wharton's jelly," which consists of stellate and irregular cells embedded in a gelatinous matrix. The blood-vessels of the cord are situated in the core, and include two allantoic or umbilical arteries which run spirally round a single umbilical vein. The terminal portion of the allantoic diverticulum projects into the embryonic end of the cord, and at first a loop of intestine protrudes into it for a short distance; the gut, however, soon recedes into the abdominal cavity.

The umbilical cord, which extends from the umbilical orifice to the centre of the placenta, is at first short and straight. As the amnion expands the length of the umbilical cord increases until, at the time of birth it measures, on an average, about 20 inches. This increase in the length of the cord allows the fœtus to float freely in the amniotic fluid, and prevents traction on the placenta.

After the middle of the second month the umbilical cord is twisted spirally, usually from right to left. It is suggested that this is due either to the great elongation of the allantoic arteries or to muscular movements of the fœtus, and it involves a rotation of the fœtus in the amniotic fluid.

The Chorion.—The chorionic area, by far the largest of the areas into which the blastoderm is divisible, lies external to the amniotic area. In most mammals it consists at first of ectoderm and entoderm, but after the extension and cleavage of the mesoderm has taken place, it is formed by ectoderm and somatic mesoderm. In man, however, it consists in the earliest stages of ectoderm alone, but on the formation and extension of the mesoderm it also acquires an inner layer of somatic mesoderm. In all cases, therefore, it eventually consists of the same two layers.

The ectoderm of the chorionic area which immediately surrounds the amniotic area thickens to form the annular placental area, and in this way the chorionic area becomes divisible into placental and non-placental regions.

When the blastodermic vesicle enters the uterus numerous ectodermal villous processes grow from the surface of the chorionic area, both in its placental and non-placental parts, and attach themselves to the uterine mucous membrane. As already pointed out in the description of the formation of the amnion, the embryonic and amniotic areas do not become attached to the uterus, but remain free from it, whilst by the approximation and fusion of its inner margins, the rapidly growing ring-like placental area is converted into a disc which intervenes between the amnion and the uterine wall.

The chorionic area after the separation of the amnion is known as the chorion or chorionic membrane.

The chorion forms the outer wall of a vesicle, the chorionic vesicle, which is the modified remains of the blastodermic vesicle and which contains the embryo, the yolk-sac, the amnion, and the allantois. It consists of an outer layer of ectoderm and an inner layer of somatic mesoderm.

The cavity of the chorion is the extra-embryonic portion of the cœlom. For a time it remains distinct, and is traversed by the allantoic stalk which unites the embryo to the inner or mesodermal layer of the placental area. The cavity is ultimately obliterated by the growth of the amnion, the latter sac expanding rapidly till its outer surface is in contact and intimately blended with the inner surface of the chorion.

The Chorionic Villi.—The villous processes which begin to grow from the surface of the chorionic area before it is separated from the amnion continue to develop after the separation of the two membranes is completed. They penetrate the surrounding uterine tissues. At first each consists of ectoderm only, but a core of vascular mesoderm is soon acquired. The villi increase in size and in complexity also, but ultimately only those in the placental area persist and continue to grow; the remainder atrophy and disappear.

Thus the placental region of the chorion eventually constitutes the main bond of union between the ovum and the mother, and it forms the fœtal part of the placenta.

THE PLACENTA.

The **placenta** is the organ of fœtal nutrition and respiration.

In it the blood-vessels of the fœtus and those of the uterus are brought into such close relationship with one another that free interchanges readily take place between the blood of the mother and that of the fœtus. In the simplest form of a placenta the fœtal villi are merely embedded in the maternal mucous membrane, and the relationship between fœtal and maternal blood is not very close. In other forms, *e.g.* the human placenta, the relation of fœtal to maternal blood is much more intimate; this involves marked modifications in the elements of the placenta, and its structure becomes correspondingly more complex. In all forms, however, the placenta consists of fœtal and maternal portions.

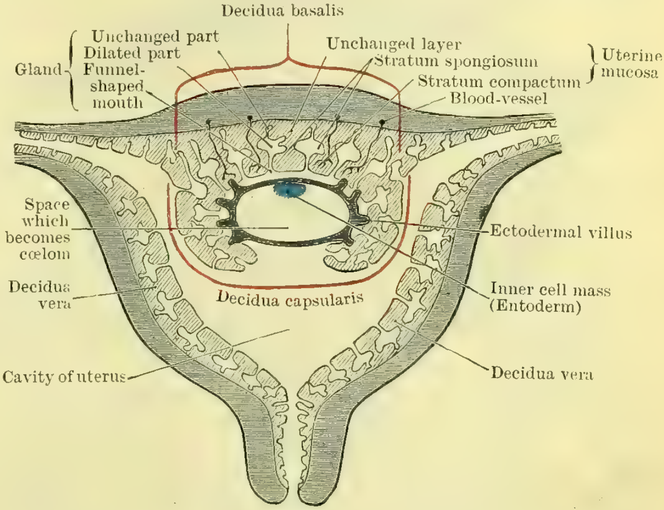


FIG. 37.—DIAGRAM, showing the relation of the young human ovum to the decidua.

The ectoderm is distinct from the inner cell mass, but as yet there is no entodermal cavity in the latter.

Before the impregnated ovum reaches the uterine cavity the mucous membrane of the uterus undergoes certain changes in preparation for its reception and retention, and the modified mucous membrane is known as the **uterine decidua.** These changes are, for the most part, hypertrophic; the vascularity of the mucous membrane is increased mainly by the dilatation of its veins and capillaries, the tubular uterine glands become elongated, irregular, and tortuous, and they dilate both at their orifices and in the deeper part of the mucous membrane; at the same time the interglandular connective tissue proliferates, and as a result the decidua is thicker, softer, and more spongy than the unaltered mucous membrane.

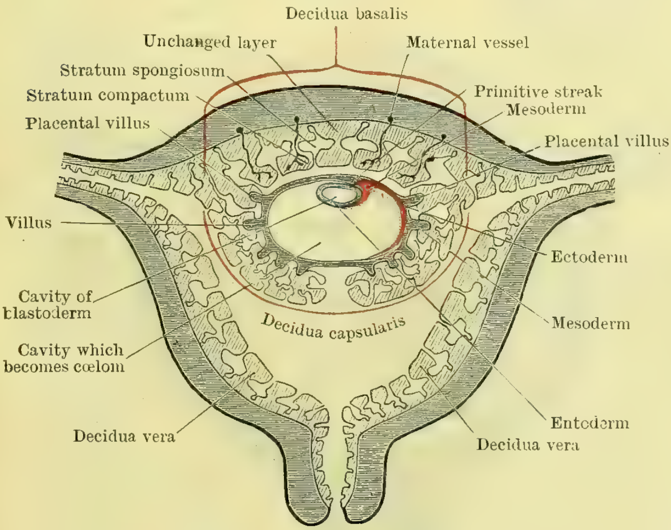


FIG. 38.—DIAGRAM, showing a further stage of development of the human ovum and its relation to the decidual tissues. The entodermal cavity or yolk-sac has appeared in the inner cell mass, and the mesoderm has commenced to extend from the primitive streak in two layers, splanchnic on the yolk-sac and somatic on the ectoderm.

When the developing ovum enters the uterus it merely rests, at first, on the surface of the decidua, but by the growth of a circular fold of the decidua it becomes gradually covered, and on the fusion of the margins of the fold it is entirely enveloped. As soon as the circular fold which surrounds the ovum arises it is possible to distinguish three decidual areas:

the fold itself is the **decidua capsularis** or **reflexa**; the part on which the ovum rests is the **decidua basalis** or **serotina**, and the rest is known as the **decidua vera.**

The **decidua basalis** lies in contact with the placental area of the chorion, *i.e.* the fœtal part of the placenta, and it forms the maternal part of this organ. In the fully developed human placenta, the fœtal and maternal tissues of which it is formed are so intimately mingled and blended together that it is impossible to say where one ends and the other begins. By a careful study, however, of a series of placentæ of different ages a fairly clear and satisfactory idea of the part played by the maternal and fœtal elements respectively, as well as of their relations to each other, may be obtained. The structural characters of the completed organ will be best understood if the two constituent parts are considered separately.

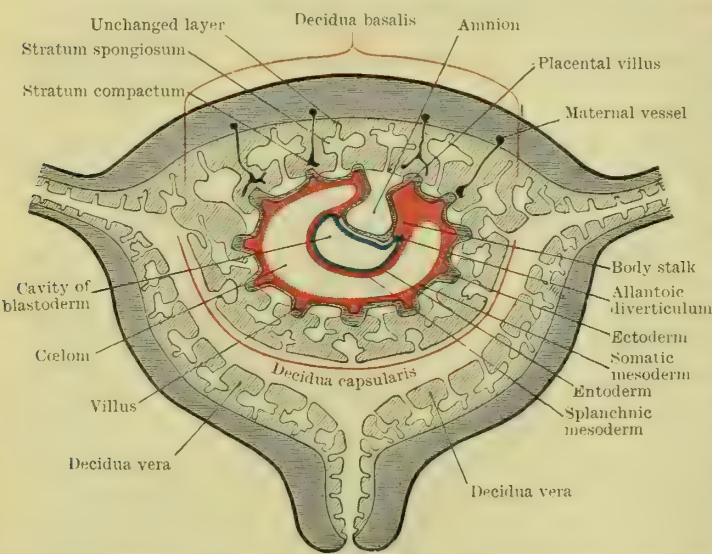


FIG. 39.—DIAGRAM, showing the completion of the decidua capsularis, the enlargement of the maternal blood-vessels in the stratum compactum of the decidua basalis, the increase of the placental villi, the formation of the amnion folds, and the appearance of the allantoic diverticulum.

The Fœtal Part of the Placenta.—The villi of the placental portion of the chorion invade and penetrate the decidua basalis, whilst the villi of the non-placental chorionic area enter the decidua capsularis.

As previously explained, in connexion with the formation both of the amnion and of the chorion, the annular placental area is converted into a circular disc. It consists, like the rest of the chorion, of ectoderm and mesoderm, and it contains ramifications of the allantoic vessels; but the ectoderm is thickened and increased, its villi are larger than those of the non-placental region of the chorion, and it is directly connected with the allantoic stalk.

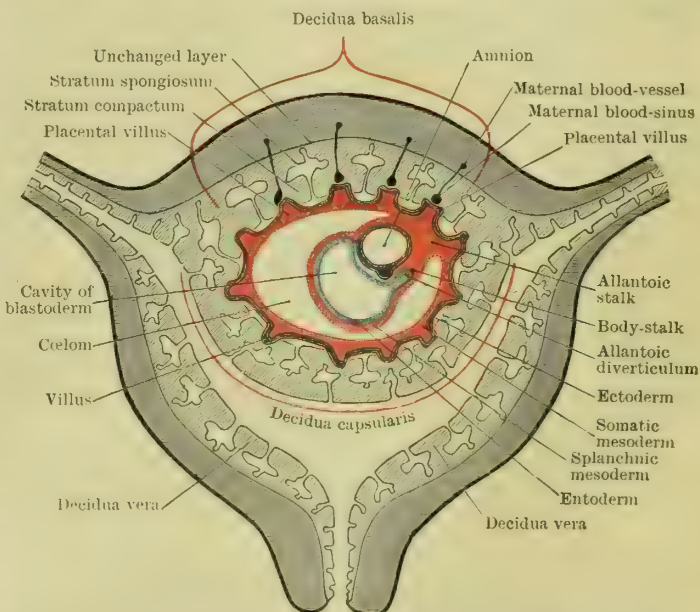


FIG. 40.—DIAGRAM, showing enlargement of the blood sinuses in the maternal part of the placenta and the closure of the amnion.

The early villi are merely ectodermal buds. They impinge against the surface epithelium of the decidua, which disappears before them. They then penetrate the sub-epithelial tissues, destroying and replacing the uterine elements. Each villus is

at an early period penetrated by an outgrowth of the subjacent mesoderm carrying branches of the allantoic vessels, and so it becomes vascular. For some time all the villi, placental and non-placental, grow and absorb nutriment from the maternal tissues, probably utilising as food the tissues which they destroy and replace; but when the decidua capsularis is thinned by the expansion of the growing ovum, the villi of the non-placental region which have penetrated it are no longer able to obtain nutrient matter, and they consequently atrophy and disappear. The placental villi, on the contrary, continue to increase; they grow in size and become more complex, and, anastomosing together, enclose the dilated maternal blood-vessels. The walls of the latter disappear, and secondary branches growing from the fœtal villi project into the enclosed spaces and float in maternal blood. When the formation of the placenta is completed, its fœtal part consists of villi, each of which possesses an external covering of two layers of ectodermal cells and a vascular mesodermal core; the villus projects into the interior of a large blood space, which is surrounded, more or less completely, by fœtal ectoderm,

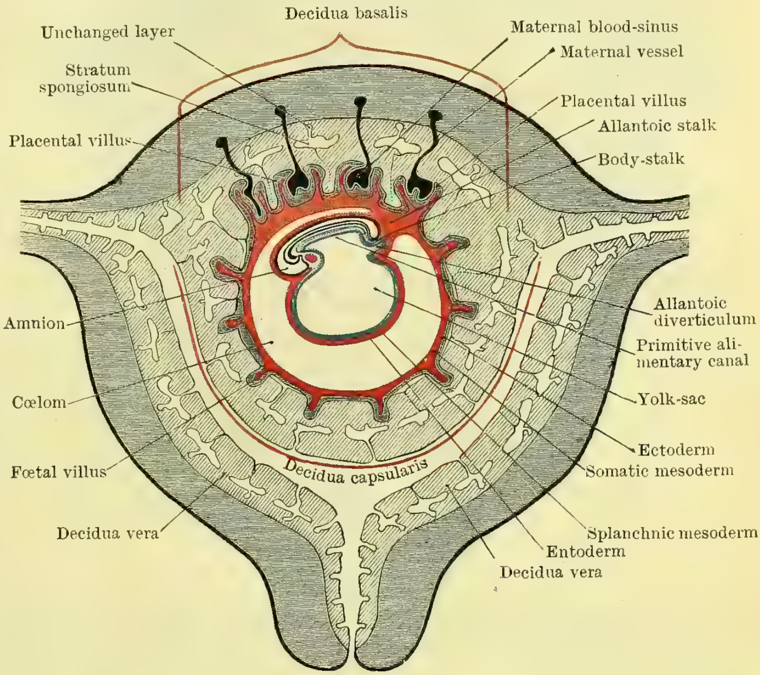


FIG. 41.—DIAGRAM, showing the fœtal ectoderm surrounding the maternal blood sinuses, the commencement of secondary fœtal villi which project into the sinuses, and the disappearance of the superficial portions of the glands.

and it is bathed by maternal blood from which it obtains the materials necessary for the nutrition and growth of the embryo, and into which it transmits effete excretory matter from the embryo.

The Maternal Part of the Placenta and the Changes in the Decidua.—The occurrence of further changes in the decidua, after the developing ovum enters the uterus, is dependent upon the retention of the ovum in the uterine cavity. These changes, therefore, only occur in what may be appropriately termed the decidua of pregnancy. They are intimately associated with and essential to the development of the maternal part of the placenta, and a more detailed and complete account of the decidua and of the modifications of its different parts is therefore necessary.

The decidua is formed by the mucous membrane of the uterus, a hollow, thick-walled, muscular organ, situated in the cavity of the pelvis. The mucous membrane contains numerous tubular glands embedded in an interglandular tissue formed of round and irregular cells. The uterine glands are lined by cubical or columnar epithelium, and they open in the cavity of the uterus on a surface which is also covered by columnar cells. The whole of the mucous membrane is plentifully supplied with blood-vessels which pass into it from the surrounding muscular walls, and it is transformed into the decidua by proliferation and hypertrophy of all its parts. The interglandular tissue increases in amount and its blood-vessels dilate, especially near the surface of the membrane; but the most striking of the early changes occur in the glands—they become longer, more tortuous, their apertures enlarge and assume a funnel-like appearance, and they dilate a short distance from

their terminations into large irregular spaces (Fig. 37). The increase of the interglandular tissue is most marked in the intervals between the dilated portions of the glands and their apertures, and when all the changes are fully established it is possible to recognise three layers of decidual tissue —(1) A superficial, relatively thick layer, in which the interglandular tissue preponderates, the **stratum compactum**; (2) A layer formed principally by the dilated portions of the glands, the **stratum spongiosum**; and (3) A thin deep portion of the membrane which contains the lower extremities of the glands, which are practically unchanged, the **unchanged layer.**

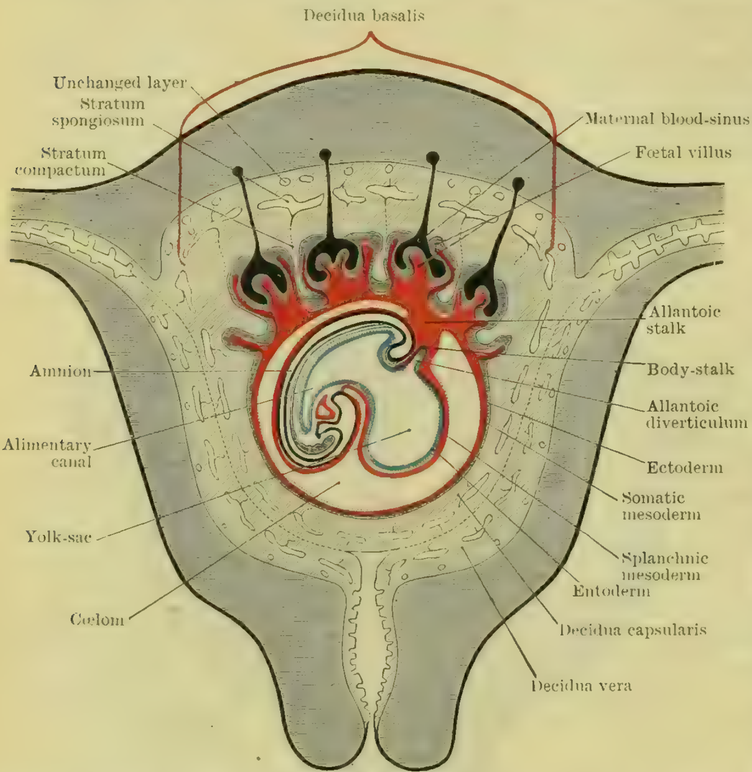


FIG. 42.—DIAGRAM, showing further growth of the placental sinuses and villi; the fusion of the decidua capsularis with the decidua vera, and the obliteration of the uterine cavity.

The **decidua capsularis** differs from the other portions of the decidua in that it is only a fold of the two superficial layers, and therefore it contains none of the deep "unchanged layer" of the decidua. Its central portion is formed by the stratum spongiosum folded upon itself, and its surfaces, external and internal, by the stratum compactum; glands open upon each surface.

The changes which occur in the decidua capsularis are due, first, to its connexion with and invasion by the chorionic villi; and, secondly, to the pressure exerted upon it by the enlarging ovum. The former influence is brought to bear whilst the decidua is still increasing; the latter, after it has reached its full development. The changes which result from its union with the chorion are the destruction and disappearance of the epithelium on its inner surface and the destruction and absorption of some of the interglandular tissue; they are due to the activity of the chorionic ectoderm which attacks and invades the uterine tissues.

The changes due to the pressure exerted by the enlarging ovum are diminution of vascularity, disappearance of the lumina of the non-dilated portions of the glands, removal of the epithelium from the spaces of the spongy layer, compression of the spaces into slits, which ultimately disappear, and the coincident atrophy of the fœtal villi, which have penetrated this portion of the decidua. All these changes result in the reduction of the decidua capsularis to a thin membrane in which no traces of the original structure are recognisable, in the fusion of the altered decidua capsularis with the decidua vera, and in the consequent obliteration of the uterine cavity.

After the fifth month the **decidua vera** also undergoes atrophic changes, but they do not proceed so far as in the decidua capsularis; nevertheless the stratum compactum is greatly reduced, the superficial epithelium and the superficial parts of the glands entirely disappear from it, the interglandular tissue becomes less

vascular, and it diminishes very considerably in thickness. The epithelium disappears from the spaces in the spongy layer, and the spaces themselves are flattened out into long slit-like clefts, in which condition they remain till the period of pregnancy is completed. The decidua vera is thus reduced to the condition of a relatively thin membrane, and its inner surface is fused with the remains of the decidua capsularis.

The Decidua Basalis.—Apart from the changes due to the invasion of the fœtal villi the most important transformations in this part of the decidua occur in the stratum compactum. The alterations in the spongy layer are similar to those which occur in the same layer of the decidua vera, viz. the lining epithelium disappears and the spaces are flattened out into a layer of cleft-like slits.

In the stratum compactum, however, much more striking changes occur; the superficial epithelium and the tubular portions of the glands disappear, but the blood-vessels become greatly dilated, and, consequently, the layer increases considerably in thickness. The terminal loops of the small blood-vessels which lie in the superficial part become converted into enormous blood-sinuses, but in the deeper part of the stratum a thin layer, which lies next the stratum spongiosum, remains relatively unchanged; this deeper part is called the **basal layer**, and through it the blood-vessels pass to and from the blood-sinuses in the more superficial portion of the membrane. When it is completed, therefore, the maternal portion of the placenta, which is the transformed decidua basalis, no longer consists of the stratum compactum, the stratum spongiosum, and the unchanged layer, but it is formed from within outwards of—(1) a layer of blood-sinuses, (2) the basal layer, (3) the modified spongy layer, and (4) the unchanged layer. The difference between the decidua basalis and the maternal part of the placenta may be tabulated as follows:—

Decidua basalis.	Maternal placenta.
Stratum compactum	Layer of blood-sinuses. Basal layer.
Stratum spongiosum	Modified stratum spongiosum.
Unchanged layer	Unchanged layer.

It must not be forgotten, however, that whilst the changes which result in the formation of the maternal placenta out of the decidua serotina are taking place the stratum compactum has been invaded by the placental villi.

The first result of this invasion is the destruction of the superficial epithelium of the decidua, which entirely disappears wherever the ectoderm of the fœtal villi comes in contact with it. Afterwards the ectoderm of the villi, always in advance of the main body, reaches and surrounds the dilated decidual vessels, destroys the intervening tissues, and ultimately replaces the endothelial walls of the vessels, which by this time have dilated into enormous spaces. Into these spaces the ramifications of the villi project, and, as the endothelial walls are destroyed, they lie directly within the cavities of the spaces, and are surrounded on all sides by maternal blood. The most peculiar feature of this part of the placenta, when fully developed, is that the whole of the maternal portion of it, except the blood, has been removed and replaced by fœtal tissues, so that, although the maternal blood continues to circulate in the same spaces which it has occupied from the first, viz. the blood-sinuses in the superficial part of the stratum compactum of the maternal decidua, yet the walls of these spaces have been replaced more or less completely by fœtal ectoderm, and, consequently, the spaces now lie in the midst of the fœtal tissues.

The invasion of the maternal by the fœtal part of the placenta proceeds as far as the basal layer, and in this region the fœtal ectoderm is directly continuous with the walls of the maternal blood-vessels at the points where they enter the sinuses.

Although the invasion of the decidua basalis is so complete, some portions of the maternal tissues persist; thus the basal layer and many strands of the stratum compactum escape destruction. The latter extend from the basal layer to the outer surface of the chorion, and they are eventually converted into fibrous strands, which divide the superficial part of the completed placenta into lobular areas.

The **completed placenta** consists therefore of closely intermingled and fused

fœtal and maternal tissues, through which both the fœtal and maternal blood streams circulate. It is well adapted on account of its peculiarities of structure to fulfil the nutritive and respiratory requirements of the embryo. The fœtal blood-stream which flows through the placental villi and the maternal blood-stream in the placental sinuses are only separated from each other by two layers of fœtal ectodermal epithelium and a small amount of fœtal mesoderm, the latter being practically reduced to the single layer of endothelial cells which form the walls of the fœtal vessels. Through these layers, by osmosis, and possibly by secretion, materials are passed both from mother to embryo and from embryo to mother, the placenta serving not only for purposes of nutrition and respiration but also as an excretory organ.

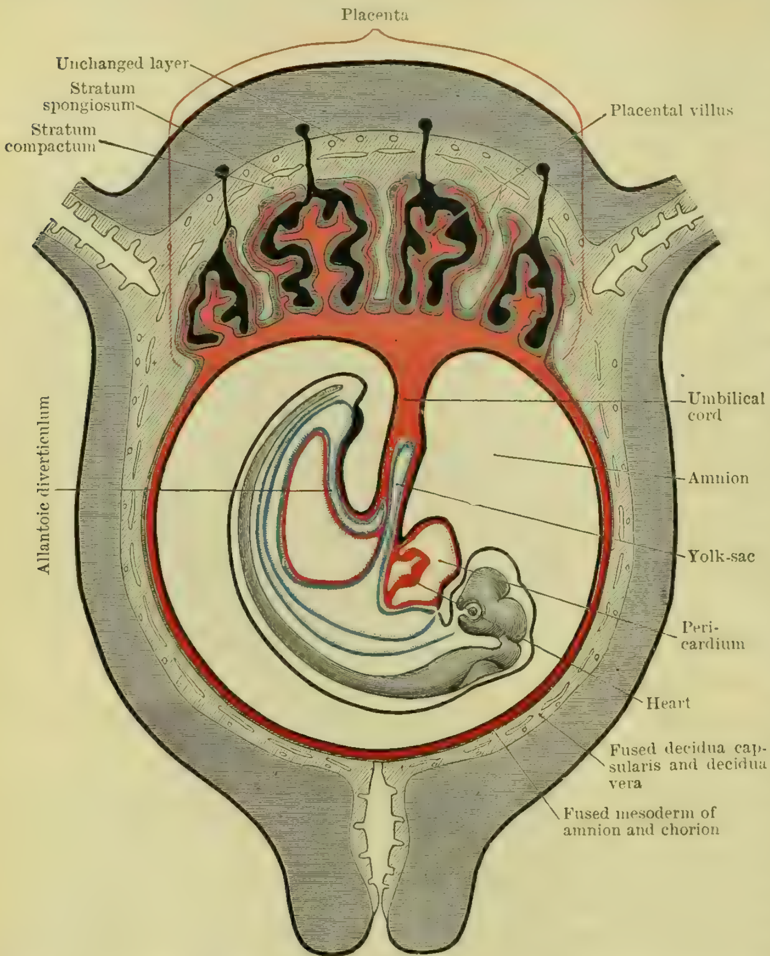


FIG. 43.—DIAGRAM. Later stage in the development of the placenta, showing the relations of the fœtal villi to the placental sinuses, the fusion of the amnion with the inner surface of the chorion, and the thinning of the fused deciduæ (capsularis and vera).

Whilst the placenta is attaining its full development the amnion is expanding, and finally its outer surface fuses with the inner surface of the chorion, consequently, the innermost portion of the placenta is provided with a covering of amnion.

The full-time placenta is a discoid mass about 20 to 25 inches (50 to 60 cm.) in circumference and $1\frac{1}{4}$ in thickness at its centre; it is much thinner, however, at its margins, where it is continuous with the membranes formed by the fused chorion, decidua vera, and decidua capsularis. Its weight is about one pound, and it consists from within outwards of the following layers:—

Fœtal	Amnion	Ectoderm. Mesoderm.
	Allantois with fœtal vessels	Mesoderm.
	Chorion	Mesoderm. Ectoderm.
Maternal	Layer of maternal blood sinuses and remains of the interglandular tissue of the stratum compactum.	
	Basal layer.	
	Modified spongy layer.	
	Unchanged layer.	

When the period of intrauterine life is completed the muscular walls of the uterus contract and the lower orifice of the uterine cavity is dilated, the fused chorion and amnion, which close the upper part of the orifice, rupture and the amniotic fluid escapes, the fœtus is then expelled, but it remains attached to the placenta by the umbilical cord. The cord is divided artificially, and after a short period the placenta and membranes are expelled. The membranes attached to the placenta consist of the fused amnion, chorion, decidua capsularis, and also the decidua vera internal to the altered spongy layer; therefore both the placenta and the membranes consist of maternal and fœtal tissues. Before the placenta and membranes are expelled the uterine decidua is separated into two parts by a cleavage which takes place in the modified stratum spongiosum. The inner portion which includes the placenta and membranes is cast off. The outer portion remains in the uterus; it consists almost entirely of the deep unchanged layer of the decidua, and from it the uterine mucous membrane is reconstructed.

THE PRIMITIVE VASCULAR SYSTEM AND THE FŒTAL CIRCULATION.

It has already been said that the ovum during its passage down the Fallopian tube lives either on its own yolk particles or upon substances absorbed from the fluids by which it is surrounded. For a time after it enters the uterus its nutrition must be provided for in a similar manner, but as soon as the chorionic villi are formed it is probable that the ectodermal cells, of which in the earliest stages they entirely consist, and which cover their surfaces in the later stages, actually eat up the decidual tissues which they invade and use them for food. This source of nutrition, however, is only sufficient for the short period during which the ovum remains relatively small and substances absorbed through the surface cells can be readily transmitted to all its parts.

In addition to the solid decidual tissues devoured by the ectodermal cells it is evident that fluids from the mother are also absorbed, for the yolk-sac and cœlom enlarge and are filled with fluid. The only sources from which these can have been derived are the uterine glands or the blood and lymph vessels of the decidua.

In all probability the fluids absorbed into the ovum contain nutritive material, and so long as the embryo is constituted by the thin layers of the early blastoderm sufficient food material can easily be absorbed. When, however, the various parts of the embryo increase in thickness and become moulded into the form of organs they are no longer in such intimate relation with the surrounding nutritive fluids, whilst, further, as their development progresses they require a greater amount of food and oxygen than they can obtain from these fluids. There is, therefore, an imperative necessity for a further supply of nutritive material by which their requirements may be satisfied, or development must cease and death ensue.

To meet this necessity the vascular system is formed. It is essentially an irrigation system consisting of a propulsive organ, the heart, and of tubular vessels, the blood-vessels, all of which contain blood. The heart propels the blood through the blood-vessels to all parts of the embryo, but the blood which is at first formed from the mesoderm of the ovum must, at least so far as its fluid part is concerned, be supplemented largely from maternal sources. It is necessary, therefore, that the fœtal blood-vessels be brought into close relation with the maternal blood-vessels at an early period. It is for this purpose, amongst others, that the large blood-sinuses are formed in the maternal portion of the placenta, and that they are surrounded and invaded by the fœtal villi, carrying in their interior branches of the fœtal blood-vessels, and as previously shown, the fœtal blood-vessels in the placenta are only separated from the maternal blood in the sinuses by their own thin mesodermal walls, and by one or two layers of ectodermal cells. When the placenta is fully formed fluids can readily pass from the maternal to the fœtal vessels, and there can be no doubt that both food and oxygen pass from the maternal blood to the fœtal blood through and by the agency of the intervening cells, whilst at the same time the waste products which are formed in the embryo pass outwards to the maternal blood.

Obviously, however, a system of vessels filled with fluid would be of little use in the general economy unless there were some means by which the fluid could be kept in constant movement. In the first instance this is accomplished by rhythmical contractions of the vessel walls, but in a short time portions of the two primitive stem-vessels which appear in the embryo are modified into a single propulsive organ, the heart, which forces the fluid, or blood, in a definite direction both through the body of the embryo, along the body-stalk or umbilical cord, according to the age of the embryo, and through the vessels in the placental villi.

We have now to consider how the blood-vessels and blood are formed.

Where, or how, the first blood-vessels appear in the human subject is not definitely known, but in other mammals they are first seen outside the body of the embryo in the wall of the yolk-sac. The outer layer of the wall of the yolk-sac consists of splanchnic mesoderm, and in that part of this layer which lies nearest the primitive alimentary canal a large number of the cells proliferate rapidly and, fusing together, form multinucleated masses of protoplasm, the **"blood islands"** of Pander.

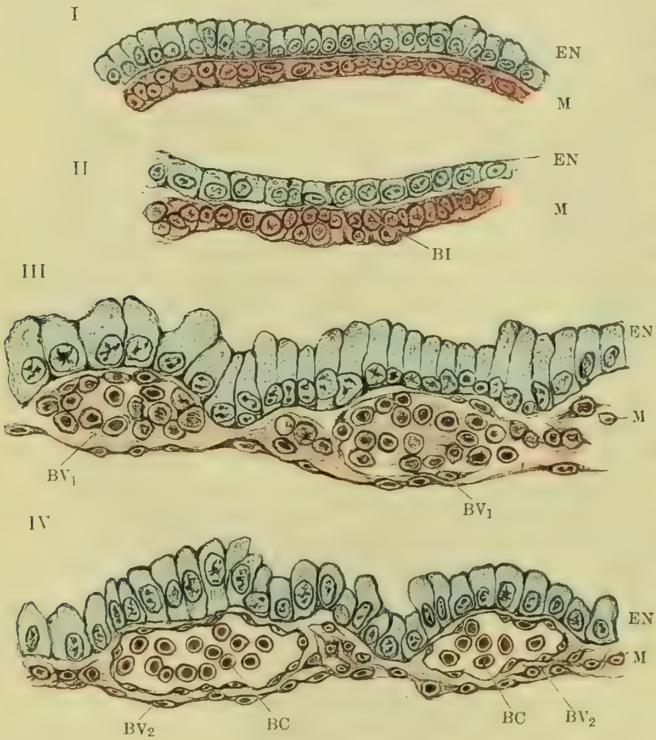


FIG. 44.—DEVELOPMENT OF BLOOD-VESSELS IN THE VASCULAR AREA OF THE RAT.

I. Entoderm and splanchnic mesoderm.
II. Proliferation of cells of mesoderm and formation of "blood islands."
III. Commencing differentiation of islands to form blood-vessels and blood-corpuscles.
IV. Completed vessels.

BC Blood-corpuscles. BV_2 Blood-vessels.
BI Blood-islands. EN Entoderm.
BV_1 Blood-islands being transformed into blood-vessels. M Mesoderm.

Soon after their appearance the blood islands anastomose together by means of nucleated processes which they throw out on all sides, and thus a nucleated protoplasmic reticulum is formed in the substance of the splanchnic mesoderm. The region in which this occurs is known as the **vascular area.** The solid nucleated reticulum is soon converted into a system of anastomosing canals, the primitive blood-vessels, by the appearance within it of numerous vacuoles which soon fuse together, whilst at the same time the nucleated protoplasm is transformed into cells. The cells which lie nearest the interior separate from each other and form the primitive blood-corpuscles, whilst those situated externally remain connected by their margins and form the endothelial walls of the embryonic vessels. The fluid which fills these first-formed vessels in the vascular area is probably derived either from the cœlom or from the yolk-sac.

The primitive blood-corpuscles are nucleated cells of a reddish colour; white or colourless blood-corpuscles appear later and those first formed are developed in the thymus gland.

Nucleated red corpuscles persist and increase in number till the end of the second month of intrauterine life; they are then gradually replaced by non-nucleated red corpuscles. The majority of the nucleated red corpuscles disappear long before birth, but a few can usually be found in the blood of the new-born child. There is

some doubt about their ultimate fate, but it is generally believed that their nuclei disappear, and that they are converted into non-nucleated corpuscles.

Directly after the appearance of the blood islands in the vascular area of the yolk-sac, and just as the folding off of the embryo commences, two short tubular vessels appear in the splanchnic layer of the pericardial mesoderm. These vessels at once extend forwards and outwards into the extra-embryonic region where they become connected with the vessels of the vascular area; they also extend backwards in the body of the embryo beneath the protovertebral somites. In the majority of mammals they at first terminate behind, as in front, on the wall of the yolk-sac, but after a time the main stems appear to be continued along the allantoic stalk to the placenta, and to give off branches to the yolk-sac. It is probable that in the human embryo also, though this has not apparently been actually observed, these main stem vessels, the primitive aortæ, end at first on the wall of the yolk-sac, but on the fourteenth day of intrauterine life, before the heart is formed, the two primitive stem-vessels pass backwards along the body-stalk to the chorion, their terminal branches entering the chorionic villi. As they pass backwards the primitive aortæ give off branches to the wall of the yolk-sac. Thus, at this period the vascular system of the human embryo consists of two longitudinal vessels which run parallel with each other, one on each side of the middle line, throughout the whole length of the embryo. They communicate anteriorly with the vessels on the yolk-sac, and terminate posteriorly in the chorion. When the circulation commences the blood flows from the anterior part of the vascular area into the anterior ends of the primitive aortæ, and passes backwards through the embryo. Some of it is returned to the vascular area by the branches which are given off to the walls of the yolk-sac; but the greater part is carried to the chorion, whence it returns by venous channels, the allantoic veins, which have been developed in the meantime, to the anterior ends of the primitive aortæ.

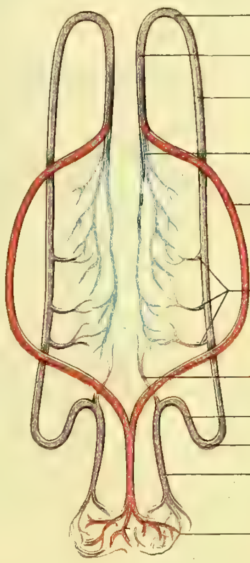


FIG. 45.—THE PRIMITIVE BLOOD-VESSELS OF THE EMBRYO.

As the cephalic and caudal folds are developed the anterior and posterior parts of the primitive aortæ are carried into the ventral wall of the body of the embryo, and thus each primitive vessel is divisible into three parts: (1) a dorsal part, the primitive dorsal aorta, which extends from the dorsal end of the mandibular arch to the cloaca, and runs beneath the protovertebral somites; (2) an anterior ventral part, situated in the dorsal wall of the pericardium and extending from the umbilicus to the ventral end of the mandibular arch; and (3) a posterior ventral part, which at first runs in the ventral wall at the side of the cloaca, and then turns backwards in the body-stalk to the placenta, but afterwards, when the posterior part of the ventral wall of the body is completed, it extends forwards from the pelvic region to the umbilical orifice, through which it passes to the umbilical cord.

The three sections are united together by two arches—an anterior arch, the first cephalic aortic arch, which passes through the mandibular arch, and a posterior arch, the caudal arch, which lies at the side of the cloaca.

In a short time four additional communications are formed between the anterior ventral and the dorsal part of each primitive aorta; they are the second, third, fourth and fifth cephalic aortic arches, each of which lies in the substance of the corresponding visceral arch.

As soon as the last cephalic aortic arch is developed the rudiments of the main vessels of the embryo are established; and by a series of transformations, for a full account of which the chapter which deals with the Vascular System must be consulted, there are formed from the vessels which have been mentioned the heart,

the aorta, the main vessels of the head and neck, the pulmonary artery and its primary branches, the common and internal iliac arteries, and the hypogastric arteries.

The blood distributed by the various arteries is returned to the heart by vessels called veins, which are developed in the substance of the mesoderm in the same manner as the arteries. From the yolk-sac the blood returns by the vitelline veins; from the alimentary canal and its appendages, through the portal and hepatic veins; from the head and neck, by the jugular veins and the superior vena cava; and from the body and lower limbs, first by the cardinal veins, and afterwards by the inferior vena cava and the azygos veins.

The heart is formed by the fusion of portions of the anterior ventral sections of the primitive aortæ behind the origins of the cephalic aortic arches, and, therefore, it is primitively a bilateral organ. Subsequently it possesses for a time a single chamber, but this is afterwards divided. During the greater part of fœtal life the heart, as in the adult, possesses four chambers—two auricles or upper chambers and two ventricles or lower chambers, right and left. The two auricles communicate with the corresponding ventricles through auriculo-ventricular apertures,

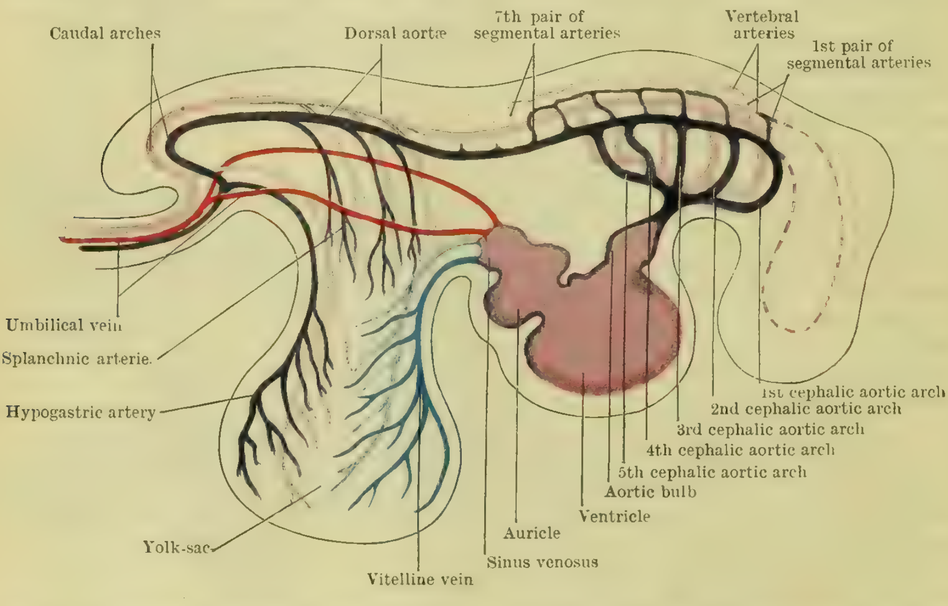


FIG. 46.—DIAGRAM OF THE BLOOD-VESSELS OF A MAMMALIAN EMBRYO AFTER THE FORMATION OF THE HEART.

and with each other through a foramen, the foramen ovale, in the septum between them.

In the adult the blood enters the right auricle by the superior and inferior venæ cavæ and the coronary sinus; from the right auricle it passes into the right ventricle, by which it is propelled through the pulmonary arteries and lungs; returning to the heart by the pulmonary veins it passes into the left auricle, and then into the left ventricle, by the contraction of which it is forced into the systemic aorta. From the aorta, by various branches, it traverses the organs and tissues of the body, and is returned again to the right auricle.

The course of the fœtal circulation differs from that of the adult; the blood passes out of the body into the placenta, to be oxygenated and purified, the lungs of the fœtus remaining functionless until the time of birth. Very little of the blood which is ejected from the right ventricle at every contraction of that chamber reaches the lungs; the greater part is transferred from the pulmonary artery to the aorta by an anastomosing channel, the ductus arteriosus, which disappears after the pulmonary circulation is established.

During the later months of fœtal life, blood enters the right auricle by the superior and inferior venæ cavæ and through the coronary sinus; by the latter the small amount only which is returning from the walls of the heart. The blood poured into the right auricle by the superior vena cava is returned from the head,

neck, upper extremities, and the thoracic walls; passing from the auricle by the right auriculo-ventricular opening it enters the right ventricle; from the right ventricle it is forced into the pulmonary artery, and a small part of it traverses the lungs and returns to the left auricle by the pulmonary veins; the main part, how-

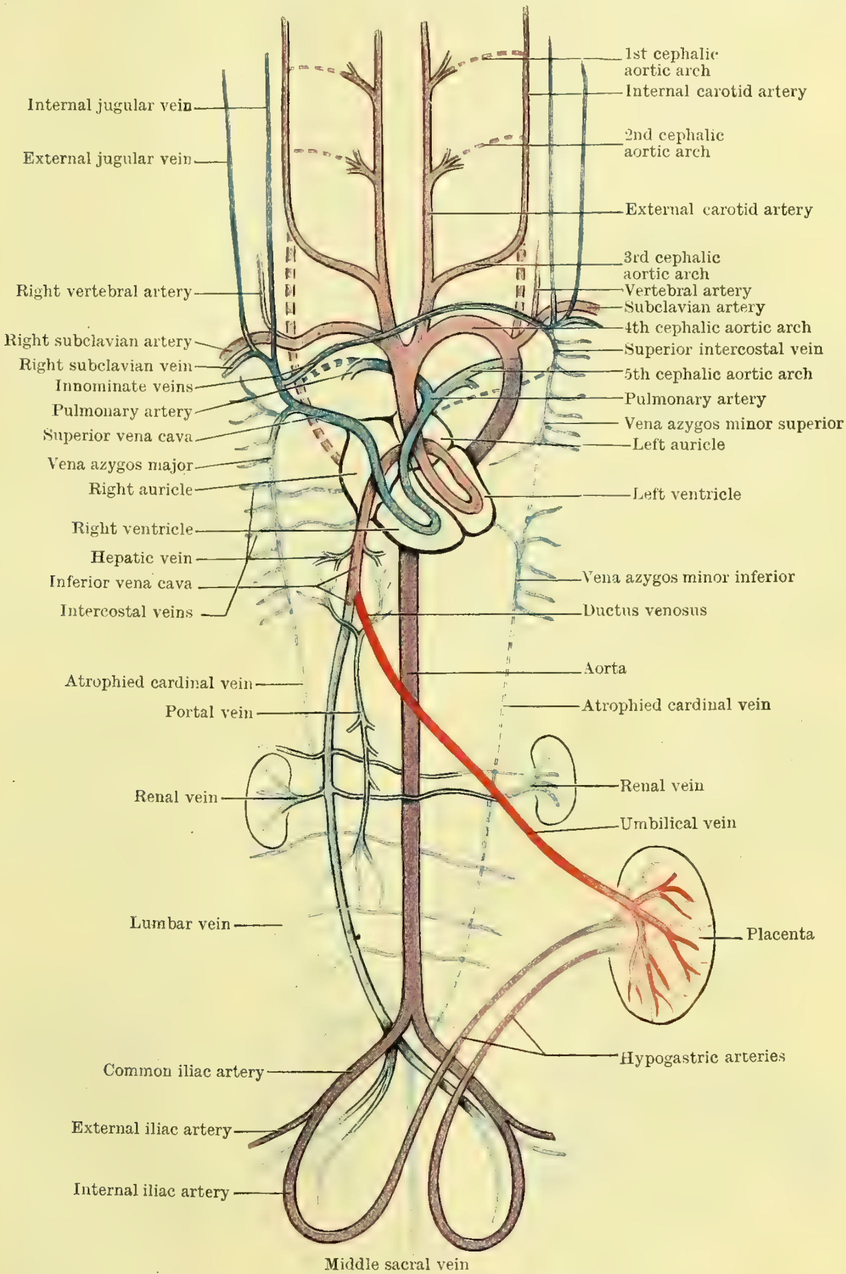


Fig. 47.—Diagram of the Fœtal Circulation.

ever, is conducted by the ductus arteriosus into the aorta at a point beyond where the main vessel of supply to the left upper extremity, the left subclavian artery, rises.

The blood which enters the right auricle by the inferior vena cava is mixed; it consists partly of purified blood from the placenta, and partly of impure blood returning from the abdomen and lower extremities. The blood from the placenta is returned to the embryo by the umbilical vein. From the umbilical vein it passes along a channel called the ductus venosus, which terminates in the upper part of the

inferior vena cava. The mixed blood from the inferior vena cava passes through the right auricle, traverses the foramen ovale in the interauricular septum, and enters the left auricle; from the left auricle it is transferred to the left ventricle through the left auriculo-ventricular opening, and the left ventricle ejects it into the aorta. From the first part of the aorta some of the blood passes into the vessels which supply the head and neck and upper extremities, the remainder mixes with the blood conveyed to the aorta by the ductus arteriosus, and the blood, thus further mixed, is in part distributed to the walls of the thorax and abdomen and to the lower extremities, and in part passes to the placenta.

Before birth, therefore, there is no pure arterial or fully oxygenated blood in the arteries of the fœtus. The blood entering the heart by the superior vena cava is venous blood from the head, neck, upper extremities, and thorax; that entering by the inferior vena cava is mixed blood, consisting of venous blood from the lower part of the body and the lower extremities, and arterial blood from the placenta. The two streams do not mix in the right auricle, but the mixed or more arterial stream passes directly through the right into the left auricle, thence into the left ventricle, and from the left ventricle into the aorta or main systemic vessel, which conveys it to all parts of the body. The different parts of the body do not, however, receive equally oxygenated blood, for the venous stream which enters the right auricle by the superior vena cava, passes through that cavity into the right ventricle; by the right ventricle it is forced into the pulmonary artery, from which some small part passes into the lungs, and so back to the left auricle by the pulmonary veins, but by far the greater part is carried by the ductus arteriosus to the aorta, which it enters beyond the origins of the vessels which supply the head, neck, and upper extremities; therefore the blood in the lower part of the aorta, which is distributed to the abdomen, lower limbs, and placenta, is much more mixed or impure (less oxygenated) than that which is distributed to the head, neck, and upper extremities from the upper part of the aorta.

SUMMARY OF THE EXTERNAL FEATURES OF THE HUMAN EMBRYO AT DIFFERENT PERIODS OF DEVELOPMENT.

The first week.—The phenomena of fertilisation and segmentation have not been observed in the human ovum, but there is no reason to believe that they differ in any essential respect from those met with in the ova of other mammals. Fertilisation probably occurs in the upper part of the Fallopian tube, and segmentation is completed in the lower part of the same canal by the eighth or tenth day, when, presumably, the ovum becomes a morula, and passes, either as such or as a blastula, into the cavity of the uterus.

The second week.—At the **twelfth day** the ovum is embedded in the uterine wall; it is a lenticular vesicle, which measures 5·5 mm. ($\frac{1}{5}$ of an inch) in length and 3·3 mm. ($\frac{1}{8}$ of an inch) in breadth. Its upper and lower surfaces are smooth and convex, the latter being somewhat flatter than the former, and it is surrounded equatorially by a broad band of villi, some of which are slightly branched. The wall of the vesicle and the villous processes which project from it consist of ectodermal cells, and in the embryonic area, which is clearly marked on the upper surface, there is an inner layer of granular nucleated corpuscles.

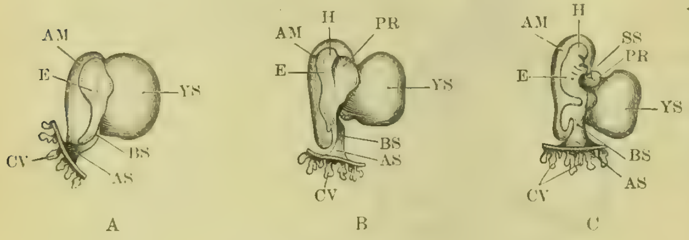


FIG. 48.

A. Human embryo at the end of the 12th day of development; B. At the end of the 13th day of development; C. At the end of the 14th day of development. (After His.)

AM. Amnion; AS. Allantoic stalk; BS. Body-stalk; CV. Chorionic villi on a segment of the chorion; E. Embryo; H. Head of embryo; PR. Pericardial region; SS. Stomatodæal depression; YS. Yolk sac.

By the end of the twelfth or the beginning of the thirteenth day the length of the ovum has increased to 6 mm. ($\frac{1}{4}$ inch), and its breadth to 4·5 mm. $\frac{1}{6}$ inch). The embryonic

area is no longer on the surface of the ovum, for the amnion folds have closed. The yolk sac is formed, and the rudiment of the allantoic duct projects backwards from its upper and posterior part. Mesoderm has formed, and it has extended round the yolk sac and over the inner surface of the chorion. The embryonic area, with the yolk-sac and the amnion, are enclosed within the blastoderm, but they remain attached to the inner surface of the chorion by a relatively thick stalk of ectodermal and mesodermal tissue, the body-stalk, which is subsequently replaced by the umbilical cord. The outer surface of the ovum, which now consists entirely of chorion, is covered with small villi into some of which mesodermal cores are projecting.

Obviously the ovum of the latter part of the twelfth day differs considerably from that of the earlier part of the same day, but the transitional stages which intervene between the two have not yet been observed. Probably, however, the inner granular layer of cells in the embryonic area, which represent the entoderm, increase and form a solid mass in which a cavity soon appears. Directly after the formation of the cavity in the entoderm the primitive streak appears, and the mesoderm, growing from it rapidly, covers the entodermal sac and spreads over the inner surface of the chorionic area. At the same time the amniotic folds form and separate from the chorion, but this separation is not effected till the mesoderm, extending backwards from the posterior end of the embryonic area, has reached and becomes connected with the inner surface of the chorion. Consequently, when the amniotic folds fuse together and separate from the remainder of the blastoderm, the embryonic area, with the yolk-sac and amnion, still remain attached to the inner surface of the chorion.

During the **thirteenth day** the embryonic area is elevated, the cephalic and caudal folds are developed, and the pericardial region becomes prominent between the head extremity of the embryo and the upper and anterior part of the yolk-sac. The neural groove and the neural folds appear; the posterior ends of the folds embrace the anterior extremity of the primitive streak on which the primitive groove is formed. At the anterior end of the primitive groove a neurenteric canal appears, forming a communication between the neural groove and the posterior end of the primitive alimentary canal.

On the **fourteenth day** the embryo is more distinctly separated from the yolk-sac; the head increases considerably in size, and its anterior part is bent downwards. The posterior part of the neural canal is completed, except at the extreme end, by the meeting and fusion of the neural folds, but it is still open anteriorly, where traces of the cerebral vesicles are present. The two halves of the heart fuse together; the single tube thus formed is slightly bent upon itself, and its outline is visible from the exterior. The pericardial region increases in size, and a distinct stomatodæal space appears between it and the anterior part of the head. The outlines of fourteen protovertebral somites are visible on the outer surface of the body.

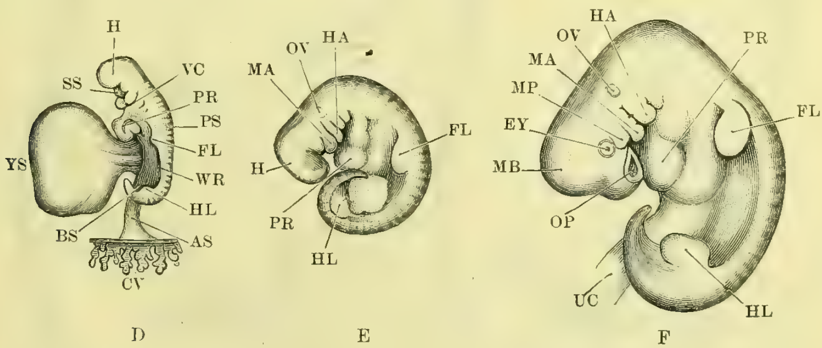


Fig. 49.

D. Human embryo at the 21st day of development; E. At the 23rd day of development: F. At the 27th day of development. (After His.)

AS. Allantoic stalk; BS. Body-stalk; CV. Chorionic villi on a segment of the chorion; EY. Eye; FL. Fore-limb; H. Head; HA. Hyoid arch; HL. Hind-limb; MA. Mandibular arch; MB. Mid-brain; MP. Maxillary process; OP. Olfactory pit; OV. Otic vesicle; PR. Pericardial region; PS. Protovertebral somite; SS. Stomatodæal space; UC. Umbilical cord; VC. Visceral cleft; WR. Wolffian ridge; YS. Yolk-sac.

The third week.—On the **fifteenth day** the auditory pits and two visceral clefts appear. The head and pericardial region enlarge, and the stomatodæal space, which increases simultaneously, becomes more defined laterally by the forward growth of the maxillary processes.

By the end of the third week Wolffian ridges appear below the ventral ends of the protovertebral somites; they are most marked in the thoracic and pelvic regions, where

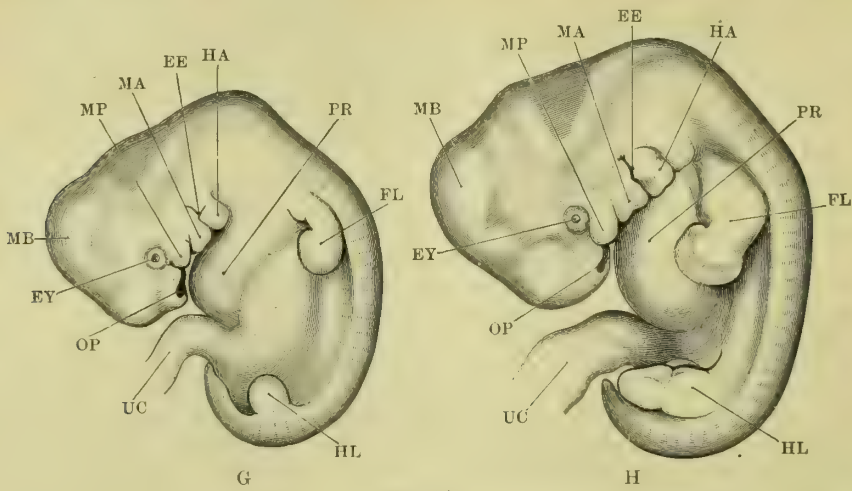


Fig. 50.

G. Human embryo at the 29th day of development; H. At the 32nd day of development. (After His.)

EE. Rudiment of ear; EY. Eye; FL. Fore-limb; HA. Hyoid arch; HL. Hind-limb; MA. Mandibular arch; MB. Mid-brain; MP. Maxillary process; OP. Olfactory pit; PR. Pericardial region; UC. Umbilical cord.

bud-like projections form the rudiments of the limbs. Four visceral clefts are visible, and there is a distinct tail.

The fourth week.—The embryo is curved upon itself, and its outline is almost

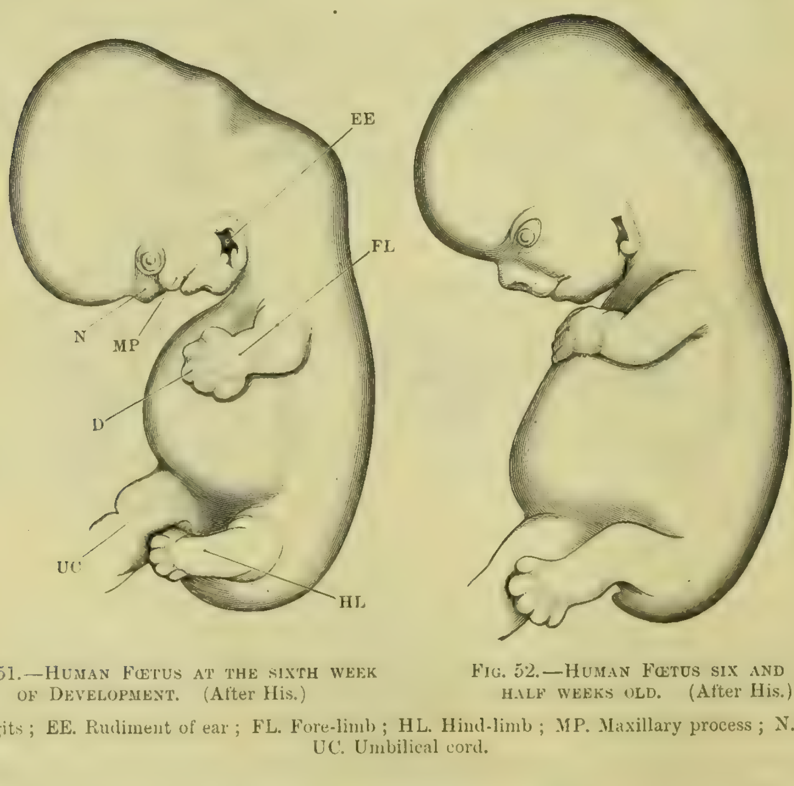


Fig. 51.—Human Fœtus at the sixth week of Development. (After His.)

Fig. 52.—Human Fœtus six and a half weeks old. (After His.)

D. Digits; EE. Rudiment of ear; FL. Fore-limb; HL. Hind-limb; MP. Maxillary process; N. Nose; UC. Umbilical cord.

circular. The visceral arches begin to overlap each other. The rudiments of the external ear are just visible as small nodules. The limb rudiments are flat, oval buds.

The fifth week.—The curvature is diminished, and the head and neck form about

half the embryo. The eye is recognisable externally. The nose begins to grow forwards, but it is still broad and flat, and the nostrils are widely apart. The nodular elements of the external ear fuse together. The segments of the limbs are defined, but the digits do not project beyond the ends of the limb-buds. The genital tubercle, the rudiment of the external generative organs, is formed.

The sixth week.—During the sixth week the increase in size is less rapid than in previous stages, but the embryo begins to assume a more distinctly human form. The head remains relatively large and it is bent at right angles to the body. The neck is better defined and appears as a constricted region between the head and trunk. The maxillary processes fuse with the lateral nasal processes, and the lips and eyelids begin to assume their characteristic form. The outer parts of all the visceral clefts except the hyo-mandibular disappear. The external ear acquires its adult form. The rotation of the limbs commences, and the fingers reach the extremity of the hand; the tail is beginning to disappear as an external projection.

The seventh week.—The flexure of the head upon the body is reduced. The nose projects more than in the preceding stage, and the chin appears. The toes reach the margins of the feet, and the projecting portion of the tail is still further reduced in length.

The eighth week.—The flexure of the head disappears. The forehead projects. The nose narrows and becomes more prominent, but the anterior nasal orifices are still directed forwards. The upper lip is completed by the fusion of the globular processes. The thumb is widely separated from the fingers, and the hand assumes a distinctly human appearance. The tail is reduced to a small nodule, and the umbilical cord is attached to the lower part of the abdominal wall. At the end of the second month the total length of the fœtus, excluding the legs, is 28 mm. ($1\frac{1}{8}$ in.).

The third month.—The head grows less rapidly and, though it is still large, it is relatively smaller in proportion to the whole body. The eyelids close, and their margins fuse together. The neck increases in length. The various parts of the limbs assume their definite proportions, and nails appear on the fingers and toes. The proctodæum is formed and the external generative organs are differentiated, so that the sex can be distinguished on external examination. The skin is a rosy colour, thin and delicate, but more consistent than in the preceding stages. By the end of the third month the total length of the fœtus, excluding the legs, is 7 cm. ($2\frac{4}{5}$ in.), including the legs, 9-10 cm. ($3\frac{3}{5}$-4 in.), and it weighs from 100-125 grammes ($3\frac{1}{2}$-$4\frac{1}{2}$ oz.).

The fourth month.—In the fourth month the skin becomes firmer, and fine hairs are developed. The disproportion between the fore and hind limbs disappears. If the fœtus is born at this period it may live for a few hours. Its total length from vertex to heels is 16-20 cm. ($6\frac{2}{5}$-8 in.), from vertex to coccyx 12-13 cm. ($4\frac{4}{5}$-$5\frac{1}{5}$ in.), and it weighs from 230-260 grammes ($8\frac{1}{8}$-$9\frac{1}{5}$ oz.).

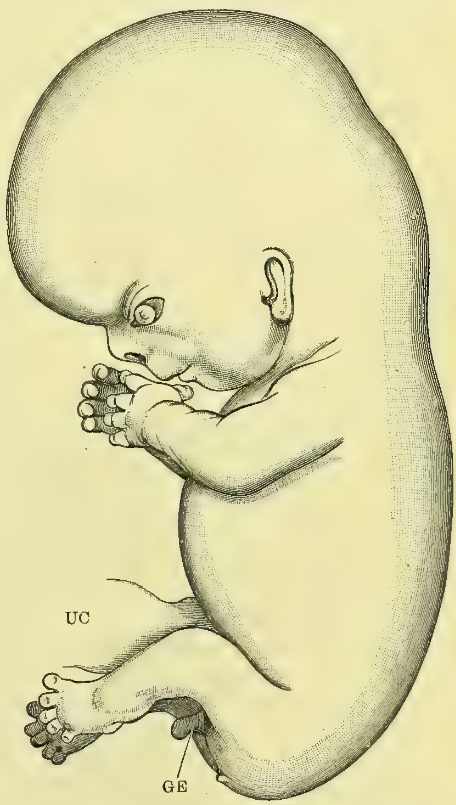


Fig. 53.—Human Fœtus eight and a half weeks old. (After His.)

GE. Genital eminence; UC. Umbilical cord.

The fifth month.—The skin becomes firmer, the hairs are more developed, and sebaceous matter appears on the surface of the body. The legs are longer than the arms, and the umbilicus is further from the pubis. At the end of the month the total length of the fœtus, from vertex to heels, is 25-27 cm. (10-$10\frac{4}{5}$ in.), from vertex to coccyx 20 cm. (8 in.), and its average weight is about half a kilogramme ($1\frac{1}{10}$ lbs.).

The sixth month.—The skin is wrinkled and of a dirty reddish colour. The hairs are stronger and darker. The deposit of sebaceous matter is greater, especially in the axillæ and groins. The eyelashes and eyebrows appear. At the end of the month the

total length of the fœtus, from vertex to heels, is from 30-32 cm. (12-$12\frac{2}{5}$ in.), and its average weight is about one kilogramme ($2\frac{1}{5}$ lbs.).

The seventh month.—The skin is still a dirty red colour but it is lighter than in the previous month. The body is more plump on account of a greater deposit of subcutaneous fat. The eyelids reopen, and the fœtus is capable of living if born at this period. Its total length at the end of the month, measured from vertex to heels, is 35-36 cm. (14-$14\frac{2}{5}$ in.), and its weight is about one and a half kilogrammes ($3\frac{1}{3}$ lbs.)

The eighth month.—The skin is completely covered with sebaceous deposit which is thickest on the head and in the axillæ and groins, and its colour changes to a bright flesh tint. The umbilicus is further from the pubis, but it is not yet at the centre of the body. The total length of the fœtus, from vertex to heels, is 40 cm. (16 in.), and its weight varies from 2 to $2\frac{1}{2}$ kilogrammes ($4\frac{1}{2}$-$5\frac{1}{2}$ lbs.)

The ninth month.—The hair begins to disappear from the body but it remains long and abundant on the head. The skin becomes paler, the plumpness increases, and the umbilicus reaches the centre of the body. At the end of the ninth month, when the fœtus is born, it measures about 50 cm. from vertex to heels (20 in.), and it weighs from 3-$3\frac{1}{2}$ kilogrammes ($6\frac{6}{10}$-$7\frac{7}{10}$ lbs.)

The age of a fœtus may be estimated approximately by Hasse's rule—viz.: Up to the fifth month the length in centimeters, the lower limbs being included, equals the square of the age in months, and after the fifth month the length in centimeters equals the age multiplied by five.

OSTEOLOGY.

THE SKELETON.

By Arthur Thomson.

The term **skeleton** (from the Greek, σκελετος, dried) is applied to the parts which remain after the softer tissues of the body have been disintegrated or removed, and includes not only the bones, but also the cartilages and ligaments which bind them together. In the restricted sense of the word the skeleton denotes the osseous framework of the body. It is in this sense that it is generally employed in human anatomy.

The skeleton serves to support the softer structures which are grouped around it, and also affords protection to many of the delicate organs which are lodged within its cavities. By the articulation of its several parts, its segments are converted into levers which constitute the passive portion of the locomotory system. Recent research has also proved that certain cells found in bone-marrow are intimately associated with the development and production of some of the corpuscles of the blood.

Bone may be regarded as white fibrous tissue which, having become calcified, has undergone subsequent changes, so as to be converted into true osseous tissue. Most probably all bone is of membranous origin, but it may pass through a stage in which cartilage plays an important part in its development. In many instances the cartilage persists, and is not converted into bone, as in the case of the articular cartilage which clothes the joint surfaces, the nasal septum, the cartilages of the nose, and the cartilages of the ribs. A persistence of the membranous condition is met with in man in the case of the tentorium cerebelli, which in some groups of animals (Carnivora) is converted into a bony partition.

Skeletal structures may be derived from each of the three layers of the trilaminar blastoderm. The **exo-skeleton** includes structures of ectodermal, and some of mesodermal origin in the shape of hair, nails, feathers, teeth, scales, armour-plates, etc., whilst the **endo-skeleton**, with which we are more particularly concerned, is largely derived from the mesoblastic tissue, but also includes the notochord, an entodermal structure which forms the primitive endo-skeleton, around which the axial skeleton is subsequently developed in the Vertebrata. The endo-skeleton is divisible into an axial portion, appertaining to the trunk and head, and an appendicular part associated with the limbs. It also includes the **splanchnic skeleton**, which comprises certain bones developed in the substance of some of the viscera, such as the os cordis and os penis of certain mammals. In man, perhaps, the cartilaginous framework of the trachea and bronchi may be referred to this system. The number of the bones of the skeleton of man varies according to age. Owing to a process of fusion taking place during growth, the number in the adult is less than the number in the child.

The following table does not include the sesamoid bones which are frequently developed in tendons, the most constant ossicles of this description being those in relation to the metacarpo-phalangeal joint of the thumb, and metatarso-phalangeal joint of the great toe.

The table represents the number of bones distinct and separable during adult life:—

		Single Bones.	Pairs.	Total.
Axial skeleton	The vertebral column	26	...	26
	The skull	6	8	22
	The sternum	1	...	1
	The ribs	...	12	24
	The hyoid bone	1	...	1
Appendicular skeleton	The upper limbs	...	32	64
	The lower limbs	...	31	62
The ossicles of the ear		...	3	6
		34	86	206

Bones are often classified according to their shape. Thus **long bones,** that is to say, bones of elongated cylindrical form, are more or less characteristic of the limbs. **Broad** or **flat bones** are plate-like, and serve as protective coverings to the structures they overlie: the bones of the cranial vault display this particular form. Other bones, such as the carpus and tarsus, are termed **short bones**; whilst the bones of the cranial base, the face, and the vertebræ, are frequently referred to as **irregular bones.**

Various descriptive terms are applied to the prominences commonly met with on a bone, such as tuberosity, eminence, protuberance, process, tubercle, spine, ridge, crest, and line. These may be articular in their nature, or may serve as points or lines of muscular and ligamentous attachment. The surface of the bone may be excavated into pits, depressions, fossæ, cavities, furrows, grooves, and notches. These may be articular or non-articular, the latter serving for the reception of organs, tendons, ligaments, vessels, and nerves. In some instances the substance of the bone is hollowed out to form an air space, sinus, or antrum. Bones are traversed by foramina and canals; these may be for the entrance and exit of nutrient vessels, or for the transmission of vessels and nerves from one region to another. A cleft, hiatus, or fissure serves the same purpose. Channels of this kind are usually placed in the line of a suture, or correspond to the line of fusion of the primitive portions of the bone which they pierce.

Composition of Bone.—Bone is composed of a combination of organic and inorganic substances in about the proportion of one to two.

Organic matter (Fat Collagen)		31·04
Mineral matter—		
Calcic phosphate	58·23	68·97
Calcic carbonate	7·32	
Calcic fluoride	1·41	
Magnesic phosphate	1·32	
Sodic chloride	·69	
		100·00

The animal matter may be removed by boiling or charring. According to the completeness with which the fibrous elements have been withdrawn, so the brittleness of the bone increases. When subjected to high temperatures the earthy matter alone remains. By soaking a bone in acid the salts may be dissolved out, leaving only the organic part. The shape of the bone is still retained, though it has now become soft, and can be bent about in any direction.

Bone may be examined either in the fresh or dry condition. In the former state it retains all its organic parts, which include the fibrous tissue in and around it, the blood-vessels and their contents, together with the cellular elements found within the substance of the bone itself, and the marrow which occupies the lacunar spaces and marrow cavity. In the dried or macerated bone most of these have disappeared, though a considerable portion of the organic matter still remains, even in bones of great antiquity and in a more or less fossil condition. Considering its nature and the amount of material employed, bone possesses a remark-

able strength, equal to nearly twice that of oak, whilst it is capable of resisting a great crushing strain; it is stated that a cubic inch of bone will support a weight of over two tons. Its elasticity is remarkable, and is of the greatest service in enabling it to withstand the shocks to which it is so frequently subjected. In regions where wood is scarce the natives use the ribs of large mammals as a substitute in the construction of their bows. Its hardness and density vary in different parts of the skeleton, and its permanency and durability exceed that of any other tissue of the body, except the enamel and dentine of the teeth. The osseous remains of a race over eighty centuries old is now being excavated in Egypt.

Structure of Bone.—The structure of the bone varies with the form of the bone examined. If a long bone be studied in section, the **shaft** or **diaphysis** will be seen to be hollow, displaying a cavity of elongated shape, which contains the soft cellular marrow. Around this, the bone is deposited in spicules so as to form a loose osseous meshwork, which becomes denser as it reaches the circumference, and gradually merges with the compact layer which forms the outer investing envelope. The extremities of the bone, usually developed from separate or secondary centres called **epiphyses**, are composed of cancellous tissue, usually finer in the grain and not, as a rule, displaying any medullary cavity. Here the confining shell of bone is thin, and displays none of the stoutness which is so characteristic of the outer layers in the shaft. In the recent condition the extremities are cartilage-covered where they enter into the formation of joints. In flat bones the osseous tissue is disposed in two compact layers, with a layer of softer cancellous bone, here called the **diploe**, sandwiched in between. There is no medullary cavity, although in certain regions the substance of the diploe may be absorbed, thus forming **air-spaces** or **air-sinuses.**

True bone differs from calcified cartilage or membrane in that it not merely consists of the deposition of earthy salts within its matrix, but displays a definite arrangement of its organic and inorganic parts. Dense bone merely differs from loose or cancellous bone in the compactness of its tissue, the characteristic feature of which is the arrangement of the osseous lamellæ to form what are called **Haversian systems.** These consist of a central or **Haversian canal** which contains the vessels of the bone. Around this the **osseous lamellæ** are arranged concentrically, separated here and there by interspaces called **lacunæ,** in which the bone corpuscles are lodged. Passing from these lacunæ are many fine channels called **canaliculi.** These are disposed radially to the Haversian canal, and pass through the osseous lamellæ. They are occupied by the slender processes of the bone corpuscles. Each Haversian system consists of from three to ten concentric rings of osseous lamellæ.

In addition to the lamellæ of the Haversian systems there are others which are termed the **interstitial lamellæ**; these occupy the intervals between adjoining Haversian systems, and consist of Haversian systems which have undergone a process of partial absorption. Towards the surface of the bone, and subjacent to the periosteal membrane which surrounds the shaft, there are lamellæ arranged circumferentially; these are sometimes referred to as the outer **fundamental lamellæ.** The **periosteal membrane** which surrounds the bone, and which plays so important a part in its development, sends in processes through the various Haversian systems, which carry with them vessels and cells, thus forming an organic meshwork around which the earthy salts are deposited.

The interior of the bone, viz. the **marrow cavity,** and the interspaces within the cancellous tissue, as well as some of the larger Haversian canals, are occupied by the **marrow** or **medulla** of the bone. This varies considerably in its composition in different bones. In the medullary cavity of the shafts of the long bones it consists mainly of fat cells, together with a few marrow cells proper, supported by a kind of retiform tissue, and is known as the **yellow marrow.** In other situations, viz. in the diploe of the cranial bones, in the cancellated tissue of the epiphyses of the long bones, the vertebræ, the sternum, and the ribs, the marrow is more fluid in its consistence, contains less fat, but is characterised by the presence of marrow-cells proper, which resemble in some respects colourless blood corpuscles. In addition to these, however, there are smaller reddish-coloured cells, akin to the nucleated red

corpuscles of the blood of the embryo. It is these cells (erythroblasts) which are concerned in the formation of the coloured corpuscles of the blood. Marrow which displays these characteristic appearances is distinguished from the yellow variety already described by being called the **red marrow.** In the diploe of the cranial bones of aged individuals the marrow, which has undergone degenerative changes, is sometimes referred to as the **gelatinous marrow.**

Apart from the adaptation of form rendered necessary by the use to which the bone is put, external influences are seen to react upon the intimate structure of the bone itself. Thus, if sections of different bones be made, the arrangement of their cancellous and dense tissue is seen to vary. In long bones the walls of the shaft are thick and strong, more particularly towards the concave side, if the shaft happens to be bent. The marrow cavity—largest towards the centre—gradually tapers towards the extremities, being encroached upon by the surrounding cancellous tissue, which is disposed in lines converging towards the extremities like the sides of a vaulted arch, thereby forming platforms on which the epiphyses are supported. The surfaces of these platforms are not smooth, but so arranged as best to withstand the strain to which the epiphyses are habitually subjected. Such provision is necessary in order to obviate the tendency to separation, which would otherwise occur prior to the complete osseous union of the diaphysis with the epiphyses. In the epiphysis itself the arrangement of the fibres of the cancellous tissue is determined by the disposition of the articular surfaces. The osseous lamellæ, as a rule, are disposed at right angles to the planes of the articular facets, whilst they are bound together by other lamellæ arranged conformably with these articular planes. The former correspond to the direction of greatest pressure, whilst the latter agree with the lines of greatest tension. In cases where there is an outstanding process projecting from the shaft, as, for example, the head and neck of the femur, a section of the bone displays a bracket-like arrangement of the osseous fibres of the cancellous tissue, which assists materially in strengthening the bone.

Ossification and Growth of Bones.—For an account of the earlier development of the skeleton the reader is referred to pp. 28 and 45. Concerning the subsequent changes which take place, these are dependent on the conversion of the scleratogenous tissue into membrane and cartilage. A characteristic of this tissue is that it contains elements which become formed into bone-producing cells, called **osteoblasts.** These are met with in the connective tissue from which the membrane bones are formed, whilst they also appear in the deeper layers of the investing tissue of the cartilage (perichondrium), and so lead to its conversion into the bone-producing layer or periosteum. All true bone, therefore, may probably be regarded as of membranous origin, though its appearance is preceded in some instances by the deposition of cartilage; in this case calcification of the cartilage is an essential stage in the process of bone formation, but the ultimate conversion into true bone, with characteristic Haversian systems, leads to the absorption and disappearance of this primitive calcified cartilage.

Membrane bones are such as have developed from fibrous tissue without having passed through a cartilaginous stage. Of this nature are the bones of the cranial vault and the majority of the bones of the face, viz. the superior maxillæ, malars, nasals, lachrymals, and palate bones, as well as the vomer. The internal pterygoid plate is also of membranous origin.

Cartilage bones are those which are preformed in cartilage, and include most of the bones of the skeleton. Their growth is often described as endochondral and ectochondral, the former term implying the deposition of membrane bone in the centre of the cartilage, while the latter signifies a deposit of membrane bone on the surface of the cartilage, the osteogenetic layer on the surface of the cartilage being called the perichondrium till once bone has been formed, when it is called the periosteum.

In the course of the development of a bone from membrane, as, for example, the parietal bone, the fibrous tissue corresponding to the position of the primary centre becomes osteogenetic, because here appear the bone-forming cells (osteoblasts), which rapidly surround themselves with a bony deposit more or less spicular in

arrangement. As growth goes on these osteoblasts become embedded in the ossifying matrix, and remain as the corpuscles of the future bone, the spaces in which they are lodged corresponding to the lacunæ and canaliculi of the fully-developed osseous tissue. From the primary centre ossification spreads eccentrically towards the margins of the bone, where ultimately the sutures are formed. Here the growth rendered necessary by the expansion of the cranium takes place through the agency of an intervening layer of vascular connective tissue rich in osteoblasts; but in course of time the activity of this is reduced until only a thin layer of intermediate tissue persists along the line of the suture, which may eventually become absorbed, leading to the obliteration of the suture by the osseous union of the contiguous bones. Whilst the expansion of the bone in all directions is thus provided for, its increase in thickness is determined by the activity of the underlying and overlying strata. These form the periosteum, and furnish the lamellæ which constitute the inner and outer compact osseous layers.

In a cartilage bone, changes of a similar nature occur. The cartilage, which may be regarded histologically as white fibrous tissue + chondro-sulphuric acid and a certain amount of lime salts, undergoes the following changes:—**First**, the cartilage cells being arranged in rows, become enlarged; **secondly**, the matrix between the cartilage cells becomes calcified by the deposition of an additional amount of lime salts; **thirdly**, the rows of cells become confluent; and **fourthly**, into the spaces so formed extend the blood-vessels derived from the vascular layer of the periosteum. Accompanying these vessels are osteoblasts and osteoclasts, the former building up true bone at the expense of the calcified cartilage, the latter causing an absorption of the newly-formed bone, and leading to its conversion into a marrow cavity, so that in due course all the cartilage or its products disappear. At the same time that this is taking place within the cartilage, the perichondrium is undergoing conversion into the periosteum, an investing membrane, the deeper stratum of which, highly vascular, furnishes a layer of osteoblast cells which serve to develop the circumferential lamellæ of the bone. It is by the accrescence of these layers externally, and their absorption internally through the action of the osteoclast cells, that growth takes place transversely. A transverse section of the shaft of a long bone shows this very clearly. Centrally there is the marrow cavity, formed primarily by the absorption of the calcified cartilage; around this the cancellous tissue produced by the partial erosion of the primary periosteal bone is disposed, whilst externally there is the dense envelope made up of the more recent periosteal growth.

Such a description, whilst explaining the growth of bone circumferentially, fails to account for its growth in length; hence the necessity in long bones for some arrangement whereby ossification may take place at one or both extremities of the shaft. This zone of growth is situated where the ossified shaft becomes continuous with the cartilaginous epiphysis. In addition, within these epiphysial cartilages calcification of the cartilage takes place centrally, just as in the diaphysis. The two parts of the bone, viz. the diaphysis and epiphysis, are thus separated by a layer of cartilage, as yet uncalcified, but extremely active in growth owing to the invasion of vessels and cells from a vascular zone which surrounds the epiphysis. The nucleus of the epiphysis becomes converted into true bone, which grows eccentrically. This arrangement provides for the growth of the shaft towards the epiphysis, and the growth of the epiphysis towards the shaft; so that as long as the active intervening layer of cartilage persists, extension of growth in a longitudinal direction is possible. Subsequently, however, at variable periods the intervening layer of cartilage becomes calcified, and true bony growth occurs within it, thus leading to complete osseous union between the shaft and epiphysis. When this has taken place all further growth in a longitudinal direction ceases. In cases where the epiphysis enters into the formation of a joint, the cartilage over the articular area persists and undergoes neither calcification nor ossification. In long bones the ossific nucleus for the shaft or diaphysis is the first to appear, and is hence often called the primary centre of ossification. The centres for the epiphyses appear subsequently at variable periods, and are referred to as the secondary centres of ossification.

From what has been said it will be gathered that the vascular supply of the bone is derived from the vessels of the periosteum. These consist of fine arteries

which enter the surface of the shaft and epiphysis; but in addition there is a larger trunk which enters the diaphysis and reaches the medullary cavity. This is called the **nutrient artery** of the bone. The direction taken by this vessel varies in different bones. In the upper limb the artery runs downwards in the case of the humerus, and upwards in the radius and ulna; in the lower limb the nutrient vessel of the femur is directed towards the upper extremity of the shaft, whilst in the tibia and fibula it follows a downward course. It is difficult to account for this difference in the arrangement of the vessels; but it has been pointed out that when all the joints are flexed, as in the position occupied by the fœtus in utero, the direction taken by the vessels is the same, and corresponds to a line passing from the head towards the tail-end of the embryo. Consequently, in the upper limb the vessels flow towards the elbow, whilst in the lower limb they pass from the knee.

The attention of anatomists has long been directed to the elucidation of the laws which regulate bone-growth. Our present knowledge of the subject may be briefly summarised in the following generalisations:—

1. In bones with a shaft and two epiphyses, the epiphysis towards which the nutrient artery is directed is the first to unite with the shaft.
2. In bones with a shaft and two epiphyses, as a rule the epiphysis which commences to ossify latest unites soonest with the shaft. (The fibula is a notable exception to this rule. See p. 231.)
3. In bones with a shaft and one epiphysis the nutrient artery is directed towards the end of the bone which has no epiphysis. (This arrangement holds good in the case of the clavicle, the metacarpus, metatarsus, and phalanges.)
4. When an epiphysis is ossified from more than one centre, coalescence takes place between the separate ossific nuclei before the epiphysis unites with the shaft.

Highly suggestive, too, are the following propositions—That ossification first commences in the epiphysis which ultimately acquires the largest relative proportion to the rest of the bone, and that the ossification of the epiphysis is also correlated with its functional importance. In cases of long bones with only one epiphysis, the epiphysis is placed at the end of the bone where there is most movement.

The **veins** which permeate the cancellous texture of the bone are large and thin-walled. They do not accompany the arteries, and, as a rule, in long bones they escape through large openings near the articular surface. In flat bones they occupy channels within the diploe, and drain into an adjacent sinus, or form communications with the superficial veins of the scalp.

The **lymphatics** are mainly periosteal, but enter the bone along with the vessels and become perivascular.

The **nerves** which accompany the arteries are probably destined for the supply of the coats of these vessels. Whether they end in the bony tissue or not is unknown.

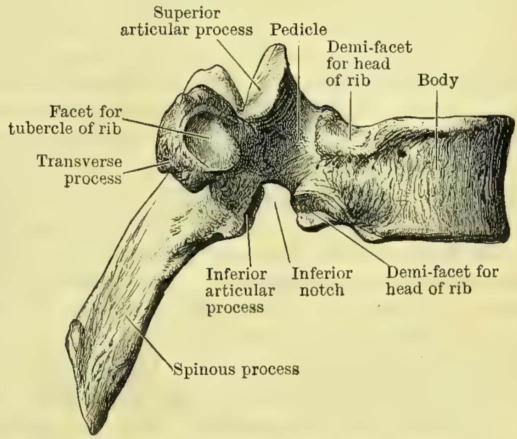
THE VERTEBRAL COLUMN.

The **vertebral column** (columna vertebralis) of man consists of thirty-three segments or **vertebræ**, placed one on the top of the other. In the adult, certain of these vertebræ have become fused together in the process of growth to form bones, the segmental arrangement of which is somewhat obscured, though even in their fully-developed condition sufficient evidence remains to demonstrate their compound nature. The vertebræ so blended are termed the **fixed** or **false vertebræ**, whilst those between which the osseous union has not taken place are described as the **movable** or **true vertebræ**. This fusion of the vertebral segments is met with at either extremity of the vertebral column, more particularly below, where the column is modified to adapt it for union with the girdle of the lower limb, and also in the region of man's degenerated caudal appendage. But a partial union of the vertebral segments also takes place above, between the two highest vertebræ, in association with the mechanism necessary to provide for the movements of the head on the column.

For descriptive purposes, the vertebral column is subdivided according to the regions through which it passes. Thus the vertebræ are described as **cervical** (vertebræ cervicales), **dorsal** or **thoracic** (vertebræ thoracales), **lumbar** (vertebræ lumbales), **sacral** (vertebræ sacrales), and **coccygeal** (vertebræ caudales), according as they lie in the regions of the neck, back, loins, pelvis, and tail. The number of vertebræ met with in these regions is fairly constant, though, as will be hereafter pointed out, variations may occur in the number of the members of the different series. The vertebræ in man are thus apportioned—7 cervical, 12 dorsal, 5 lumbar, 5 sacral, and 4 or 5 coccygeal; the three former groups comprise the **true** or **movable** vertebræ, the two latter the **false** or **fixed** vertebræ. The **vertebral formula** may be thus expressed:—

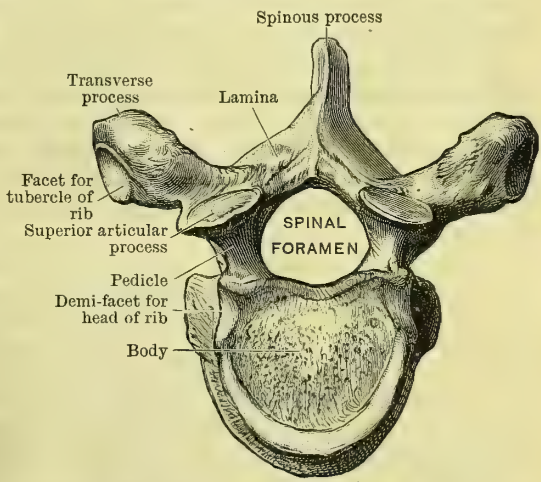
Movable or **True Vertebræ.**			**Fixed** or **False Vertebræ.**		
Cervical.	Dorsal.	Lumbar.	Sacral.	Coccygeal.	
7	12	5	5	4	= 33

The **vertebræ** of which the column is built up, though displaying great diversity of characters in the regions above enumerated, yet preserve certain features in common. All possess a solid part, **centrum** or **body** (corpus vertebræ); all have **articular processes** by which they are joined to their fellows; most have **muscular processes** developed in connexion with them; whilst the majority display a **vertebral** or **spinal foramen** (foramen vertebrale) formed by the union of a bony **arch** (arcus vertebræ) with the body. These common characters may best be studied by selecting for description an intermediate member of the series. For this purpose one of the middle or lower thoracic vertebræ may be chosen.



(As viewed from the right side.)

A typical vertebra may be described as consisting of a **body** or **centrum** (corpus vertebræ) composed of a mass of spongy bone, more or less cylindrical in form. The size and shape of the body is liable to considerable variation according to the vertebra examined. The upper and lower surfaces of the body are very slightly concave from before backwards and from side to side, due to the thickening of the bone around its margins. In the recent condition these surfaces afford attachment for the intervertebral discs which are placed like pads between the bodies of the movable members of the series. The circumference of the body, formed as it is of more compact bone than the interior, is usually slightly concave from above downwards, though it becomes flat behind, where the body forms the anterior boundary of the spinal or vertebral foramen, at which point it is usually slightly concave from side to side. The vertical surfaces of the body are pierced here and there by foramina for the



Figs. 54, 55.—Fifth Thoracic Vertebra.
(As viewed from above.)

passage of nutrient vessels, more particularly behind, where a depression of considerable size receives the openings of the canals through which some of the veins escape. Connected with the body posteriorly there is a bony **arch** (arcus vertebræ) which, by its union with the body, encloses a foramen of variable size, the **spinal** or **vertebral foramen** (foramen vertebrale). When the vertebræ are placed on the top of each other these foramina form with the uniting ligaments a continuous canal—**spinal** or **neural canal**—in which the spinal cord with its coverings is lodged. The **arch,** which is formed by the union of the **pedicles** and **laminæ,** besides enclosing the spinal foramen, also supports a certain number of processes; of these, some are outstanding, and may be regarded as a series of levers to which muscles are attached, whilst others are **articular** and assist in uniting the different vertebræ together by means of a series of movable joints. The **pedicles** are the bars of bone which pass from the back of the body of the vertebræ on either side to the points where the articular processes are united to the arch. The pedicles are compressed laterally, and have rounded superior and inferior borders. Since the vertical breadth of the pedicles is not as great as the thickness of the body to which they are attached, it follows that when the vertebræ are placed one above the other a series of intervals is left between the pedicles of the different vertebræ. These spaces, enclosed in front by the bodies of the vertebræ and their intervertebral discs, and behind by the coaptation of the articular processes, form a series of holes communicating with the neural or spinal canal; these are called the **intervertebral foramina** (foramina intervertebralia), and allow of the transmission of spinal nerves and vessels. As each intervertebral foramen is bounded above and below by a pedicle, the grooved surfaces in correspondence with the upper and lower borders of the pedicles are called the **upper** and **lower intervertebral grooves** or **notches** (incisura vertebralis superior et inferior). Posteriorly, the two pedicles are united by two somewhat flattened plates of bone—the **laminæ,** which converge towards the middle line, and become fused with the root of the projecting **spinous process** (processus spinosus). The breadth of the laminæ and their sloping arrangement are such, that when the vertebræ are articulated together they leave little space between them, thus enclosing fairly completely the neural canal, of which they form the posterior wall. The edges and inner surfaces of the laminæ are rough for the attachment of the ligaments which bind them together.

The **muscular processes** are three in number, viz. two **transverse processes**—one on either side—and one central or median, the **spinous process.** The former (processus transversus) project outwards on either side from the arch at the point where the pedicle joins the lamina. The latter (processus spinosus) extends backwards in the middle line from the point of fusion of the laminæ. The spinous processes display much variety of length and form.

The **articular processes** (zygapophyses), four in number, are arranged in pairs—one superior, the other inferior; the former are placed on the upper surface of the arch where the pedicles and laminæ join, the latter below the arch in correspondence with the superior. Whilst differing much in the direction of their articular surfaces, the upper have generally a backward tendency, whilst the lower incline forwards.

THE TRUE OR MOVABLE VERTEBRÆ.

The Cervical Vertebræ.

The **cervical vertebræ** (vertebræ cervicales), seven in number, can be readily distinguished from all the other vertebræ by the fact that their transverse processes are pierced by a foramen. The two highest, and the lowest, require special description; the remaining four conform to a common type.

Their **bodies**, the smallest of all the true vertebræ, are oblong in shape, the transverse diameter being much longer than the antero-posterior width. The upper surface, which slopes from behind forwards and downwards, is concave from side to side, owing to the marked projection of its lateral margins. Its anterior lip is rounded off, whilst its posterior edge is sharply defined.

The inferior surface, which is more or less saddle-shaped, is directed downwards and backwards. It is convex from side to side, and concave from before backwards, with a slight rounding off of the projecting anterior lip. The vertical diameter of the body is small in proportion to its width. The anterior surface is flat in the middle line, but furrowed laterally. The posterior surface, which is rough and pierced by many small foramina, is flat from side to side and above downwards; it forms in its entire extent the anterior wall of the spinal foramen. The lateral aspects of the body, particularly in their upper parts, are fused with the costal parts of the transverse processes, and form the inner wall of the vertebrarterial foramen (foramen transversarium).

The **pedicles** which spring from the posterior half of the lateral aspects of the body, about equi-distant from their upper and lower margins, are directed horizontally backwards and outwards. The **superior** and **inferior notches** are nearly equal in depth.

The **laminæ** are long, and about as wide as the body of the bone is thick.

The **spinal foramen** is larger than in the thoracic and lumbar regions; its shape is triangular, or more nearly semi-lunar.

The **transverse processes**, so called, are pierced by the vertebrarterial foramen

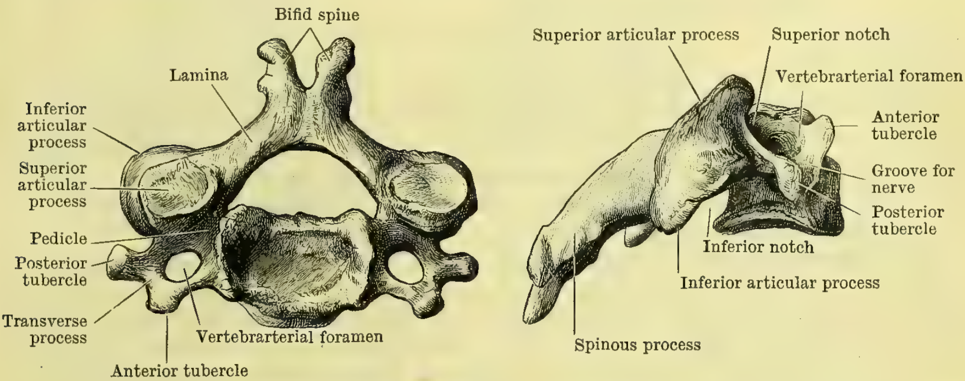


FIG. 56.—FOURTH CERVICAL VERTEBRA FROM ABOVE AND FROM THE RIGHT SIDE.

(foramen transversarium). They consist of two parts—the part behind the foramen, which springs from the neural arch and is the true transverse process, and the part in front, which is homologous with the ribs in the thoracic part of the column. These two processes, united externally by a bridge of bone, which thus converts the interval between them into a foramen, terminate in two tubercles, known respectively as the **anterior** and **posterior tubercles.** The general direction of these processes is outwards, slightly forwards, and a little downwards, the anterior tubercles lying internal to the posterior. The two tubercles are separated above by a groove directed outwards, downwards, and forwards; along this the spinal nerve trunk passes. The **vertebrarterial foramen** (foramen transversarium), often subdivided by a spicule of bone, is traversed by the vertebral artery and vein in the upper six vertebræ. The **spinous processes**, which are directed downwards, are short, compressed vertically, and bifid. The **articular processes** are supported on cylindrical masses of bone fused with the arch where the pedicles and laminæ join. These cylinders are sliced away obliquely above and below, so that the superior articular facets, more or less circular in form, are directed upwards and backwards, whilst the corresponding inferior surfaces are turned downwards and forwards.

First Cervical Vertebra or **Atlas.**—This bone may be readily recognised by the absence of the body and spinous process. It consists of two **lateral masses,** which support the articular and transverse processes. The lateral masses are themselves united by two curved bars of bone, the **anterior** and **posterior arches,** of which the former is the stouter and shorter. Each **lateral mass** is irregularly six-sided, and so placed that it lies closer to its fellow of the opposite side in front than behind. Its upper surface is excavated to form an elongated **oval facet,** concave from before backwards, and inclined obliquely inwards; not infrequently this

articular surface displays indications of division into two parts. These facets are for the reception of the condyles of the occipital bone.

The **inferior articular facets** are placed on the under surfaces of the lateral masses. Of circular form, they display a slight side-to-side concavity, though flat in the antero-posterior direction. Their position is such that their surfaces incline downwards and slightly inwards. They rest on the superior articular processes of the second cervical vertebra. Springing from the anterior and inner aspects of the lateral masses, and uniting them in front, is a curved bar of bone, the **anterior arch** (arcus anterior); compressed on either side, this is thickened centrally so as to form on its anterior aspect the rounded **anterior tubercle** (tuberculum anterius). In correspondence with this on the posterior surface of this arch is a **circular facet** (fovea dentis) for articulation with the odontoid process of the second cervical vertebra (axis).

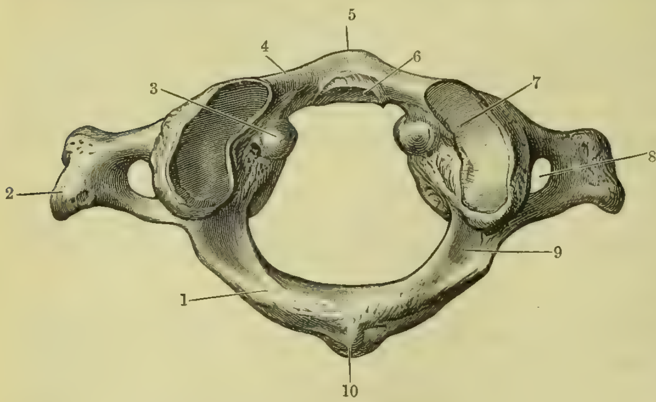


FIG. 57.—THE ATLAS FROM ABOVE.

1. Posterior arch.
2. Transverse process.
3. Tubercle for transverse ligament.
4. Anterior arch.
5. Anterior tubercle.
6. Surface for articulation with odontoid process.
7. Superior articular process.
8. Foramen for vertebral artery.
9. Groove for vertebral artery.
10. Posterior tubercle.

The inner surface of the lateral mass is rough and irregular, displaying a little **tubercle** for the attachment of the transverse ligament which passes across the space included between the two lateral masses and the anterior arch, thus holding the odontoid process of the axis in position. Behind each tubercle there is usually a deep pit, opening into the bottom of which are the canals for the nutrient vessels.

External to the lateral mass, and principally from its upper half, the transverse process arises by two roots which include between them the vertebrarterial foramen. The **transverse process** is long, obliquely compressed, and down-turned; the anterior and posterior tubercles are no longer distinguishable, as they have fused to form one mass.

The **posterior arch** arises in part from the posterior surface of the lateral mass, and in part from the posterior root of the transverse process. Compressed from above downwards anteriorly, where it bounds a groove which curves around the posterior aspect of the superior articular process and is also continuous externally with the vertebrarterial foramen, the posterior arch becomes thicker mesially, where it displays posteriorly a rough irregular projection—the **posterior tubercle** (tuberculum posterius), the feeble representative of the spinous process. A prominent little tubercle, arising from the posterior extremity of the superior articular process, overhangs the groove above mentioned, and not infrequently becomes developed so as to form a bridge of bone across it, converting the groove into a canal through which the vertebral artery and the first cervical or suboccipital nerve pass—a condition normally met with in many animals. It is noteworthy that the grooves along which the two highest spinal nerves pass lie behind the articular processes, in place of in front, as in other parts of the column.

The **ring** formed by the lateral masses and the anterior and posterior arches is of irregular outline. The anterior part, cut off from the rest by the transverse ligament, serves for the lodgment of the odontoid process of the axis; the larger part behind corresponds to the upper part of the neural or spinal canal.

Variations.—The vertebrarterial foramen is often deficient in front. Imperfect ossification occasionally leads to the anterior and posterior arches being incomplete. The superior articular surfaces are occasionally partially or completely divided into anterior and posterior portions. In some instances the extremity of the transverse process has two tubercles. The transverse

process may, in rare cases, articulate with a projecting process (paroccipital) from the under surface of the jugular process of the occipital bone (see p. 109). An upward extension from the median part of the anterior arch, due probably to an ossification of the anterior occipito-atlantal ligament, may articulate with the anterior surface of the summit of the odontoid process of the axis. Allen has noticed the articulation of the superior border of the posterior arch with the posterior border of the foramen magnum. Cases of partial or complete fusion of the atlas with the occipital bone are not uncommon (see p. 109).

Second Cervical Vertebra, Axis, or **Epistropheus.**—This is characterised by the presence of the tooth-like **odontoid process** (dens) which projects upwards from the superior surface of the body. Slightly constricted where it joins the body, the odontoid process tapers to a blunt point superiorly, on the sides of which there are surfaces for the attachment of the odontoid or check ligaments. When the atlas and axis are articulated together this process lies behind the anterior arch of the atlas, and displays on its anterior surface an oval or circular facet which articulates with that on the posterior surface of the anterior arch of the atlas. On the

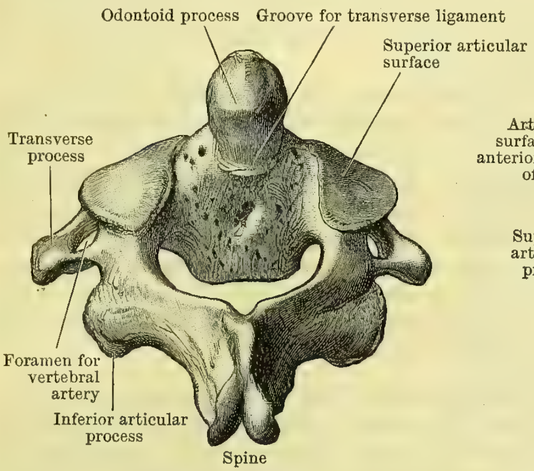


Fig. 58.—Axis from Behind and Above.

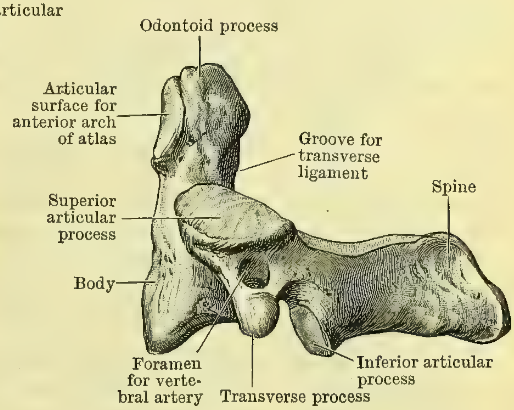


Fig. 59.—Axis from the Left Side.

posterior aspect of the neck of the odontoid process there is a shallow groove which receives the transverse ligament which holds it in position.

The anterior surface of the **body** has a raised triangular surface, which ends superiorly in a ridge passing upwards to the neck of the odontoid process. The **pedicles** are concealed above by the superior articular processes; inferiorly, they are deeply grooved. The **laminæ**—prismatic on section—are thick and strong, ending in a stout, broad, and **bifid spinous process,** the under surface of which is deeply grooved, whilst its sides meet superiorly in a ridge. Placed over the pedicles and the anterior root of the transverse processes are the **superior articular surfaces.** These are more or less circular in shape, slightly convex from before backwards, flat from side to side, and have a direction upwards and a little outwards. They are channelled inferiorly by the vertebrarterial foramina which turn outwards beneath them. The grooves by which the second cervical nerves leave the neural canal cross the laminæ immediately behind the superior articular processes. The **inferior articular processes** agree in their form and position with those of the remaining members of the series, and are placed behind the inferior intervertebral notches.

The **transverse process** is markedly down-turned, with a single pointed extremity.

Variations.—In some instances the summit of the odontoid process articulates with a prominent tubercle on the anterior border of the foramen magnum (third occipital condyle, see p. 109). Bennet (*Trans. Path. Soc. Dublin*, vol. vii.) records a case in which the odontoid process was double, due to the persistence of the primitive condition in which it is developed from two centres. Occasionally the odontoid process fails to be united with the body of the axis, forming an os odontoideum comparable to that met with in the crocodilia (Giacomini, Romiti, and Turner). The vertebrarterial foramen is not infrequently incomplete, owing to the imperfect ossification of the posterior root of the transverse process.

The **seventh cervical vertebra**, or **vertebra prominens**, receives the latter name from the outstanding nature of its **spinous process**, which ends in a single broad tubercle. This forms a well-marked surface projection at the back of the root of the neck. The **transverse processes** are broad from above downwards; they project considerably beyond those of the sixth. The maximum width between their extremities agrees with that between the transverse processes of the atlas, these two constituting the widest members of the cervical series. The **vertebrarterial foramen** is small. Not infrequently the costal element is separate from the true transverse process, thus constituting a **cervical rib**.

Variations.—The vertebrarterial foramen may be absent on one or other side.

Thoracic Vertebræ.

The **dorsal** or **thoracic vertebræ** (vertebræ thoracales), twelve in number, are distinguished by having facets on the sides of their bodies for the heads of the ribs, and in most instances also articular surfaces on their transverse processes for the tubercles of the ribs (Figs. 54 and 55, p. 73).

The **body** is described as characteristically heart-shaped, though in the upper and lower members of the series it undergoes transition to the typical forms of the cervical and lumbar vertebræ respectively. Its antero-posterior and transverse widths are nearly equal; the latter is greatest in line with the facets for the heads of the rib. The bodies are slightly thicker behind than in front, thus adapting themselves to the anterior concavity which the column displays in this region. The bodies of the second to the ninth inclusive, each possess four **costal demi-facets**—a superior pair placed on the upper margins of the body, close to the junction of the pedicle with the centrum, and an inferior pair situated on the lower edge, close to and in front of the inferior intervertebral grooves.

When contiguous vertebræ are articulated, the upper pair of demi-facets of the lower vertebra coincide with the lower demi-facets of the higher vertebra, and, together with the intervening intervertebral disc, form an articular cup for the reception of the head of a rib. Of these facets on the body the upper pair are the primary articular surfaces for the head of the rib; the lower are only acquired secondarily. Moreover, these facets, though apparently placed on the body, are in reality developed on the sides of the pedicles behind the line of union of the pedicles with the centrum (neuro-central synchondrosis), as will be explained hereafter.

The **pedicles** are short and thick, and directed backwards and slightly upwards. The superior notch is faintly marked; the inferior notch is deep. The **laminæ** are broad, flat, and sloping, having sharp upper and lower margins. When the vertebræ are superimposed the latter overlap the former so as to form an imbricated arrangement. The **spinal foramen** is smaller than in the cervical and lumbar regions, and nearly circular in shape.

The **spinous processes** vary in length and direction, being shorter and more horizontal in the upper and lower members of the series, longest and most oblique in direction towards the middle of the series. All have a downward inclination, and are so arranged that they overlap one another. Triangular in section where they spring from the neural arch, they become laterally compressed towards their extremities, which are capped by more or less distinct tubercles. The **transverse processes** are directed backwards and outwards, and a little upwards. They gradually decrease in size and length from above downwards. Each has a somewhat expanded extremity, the anterior surface of which, in the case of the upper ten vertebræ, is hollowed out in the form of a circular facet for articulation with the tubercle of the rib which rests in the upper demi-facet of the vertebra to which the transverse process belongs. The **superior articular processes** are vertical and have their surfaces directed backwards, slightly upwards, and a little outwards; the **inferior**, correspondingly forwards, downwards, and inwards.

Certain of the dorsal vertebræ display characters by which they can readily be recognised. These are the first, tenth, eleventh, and twelfth, and sometimes the ninth.

The **first dorsal vertebra** resembles the seventh cervical in the shape of its body and the length and direction of its spine. There is an entire facet on either side of the body for the head of the first rib, and one demi-facet on each side at the lower border of its body, to complete the socket for the head of the second rib. Its **transverse processes** are long, and the superior inter-vertebral notch is better marked than in other members of the dorsal series. The superior articular surfaces are directed backwards and upwards, not outwards as in the lower series.

The **ninth dorsal vertebra** occasionally has only the upper pair of demi-facets on its body; at other times it conforms to the usual type.

The **tenth dorsal vertebra** may have only one complete costal facet on each side for the X. rib, though sometimes the articular socket may be completed by the ninth dorsal vertebra. The facet on the transverse process is generally small, and sometimes absent.

The **eleventh dorsal vertebra** has a complete circular facet on the outer side of each pedicle for articulation with the XI. rib. Its transverse processes are short and stunted, and have no facets.

The **twelfth dorsal vertebra** has a single facet on the pedicle on each side for the XII. rib. Its transverse processes, which have no facets, are broken up into smaller tubercles, called respectively the external, superior, and inferior tubercles. These are homologous with the transverse mammillary and accessory processes of the lumbar vertebræ. Indications of these processes may also be met with in the tenth and eleventh dorsal vertebræ. The twelfth dorsal vertebra may usually be distinguished from the eleventh by the arrangement of its inferior articular processes, which resemble those of the lumbar series in being out-turned;

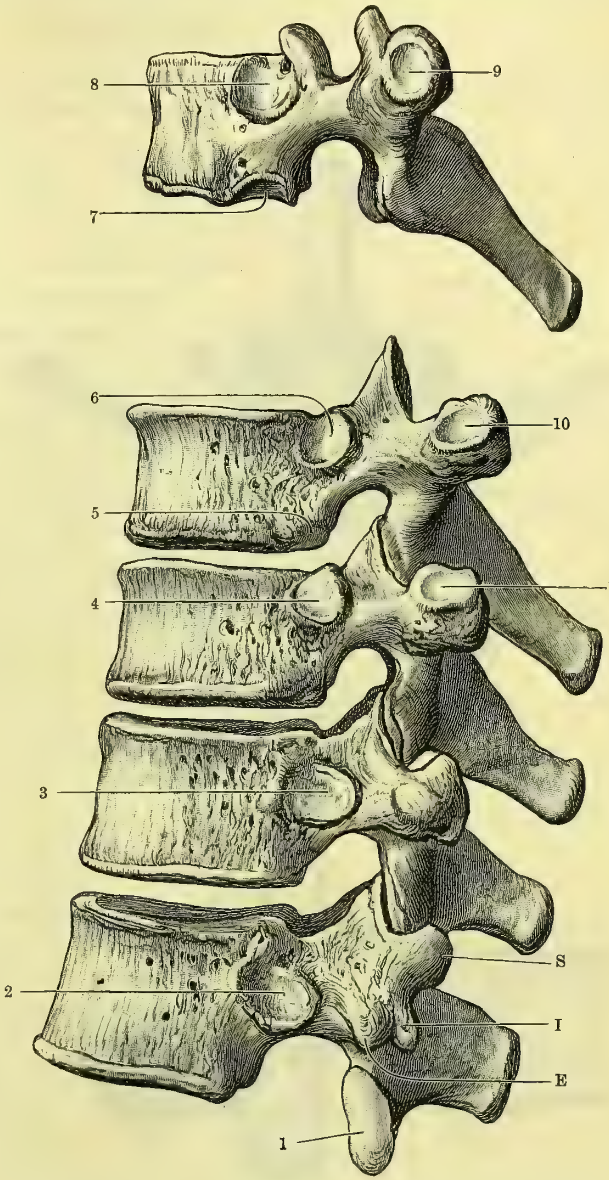


Fig. 60.—First, Ninth, Tenth, Eleventh, and Twelfth Thoracic Vertebræ from the Left Side.

1. Inferior articular process with out-turned facet.
2. Single facet for head of XII. rib; no facet on transverse process.
3. Single facet for head of XI. rib; no facet on transverse process.
4. Single or demi-facet for head of X. rib.
5. Occasional demi-facet for head of X. rib.
6. Demi-facet for head of IX. rib.
7. Demi-facet for head of II. rib.
8. Single facet for head of I. rib.
9. Facet on transverse process for tuberosity of I. rib.
10. Facet on transverse process for tuberosity of IX. rib.
11. Facet on transverse process for tuberosity of X. rib.

S. Superior, I. Inferior, E. External — Tubercles corresponding to — Mammillary, Accessory, Transverse of lumbar.

but the eleventh occasionally displays the same arrangement, in which case it is not always easy to distinguish between them.

Lumbar Vertebræ.

The **lumbar vertebræ** (vertebræ lumbales), five in number, are the largest of the movable vertebræ. They have no costal articular facets, nor are their transverse processes pierced by a foramen. In this way they can be readily distinguished from the members of the cervical and thoracic series.

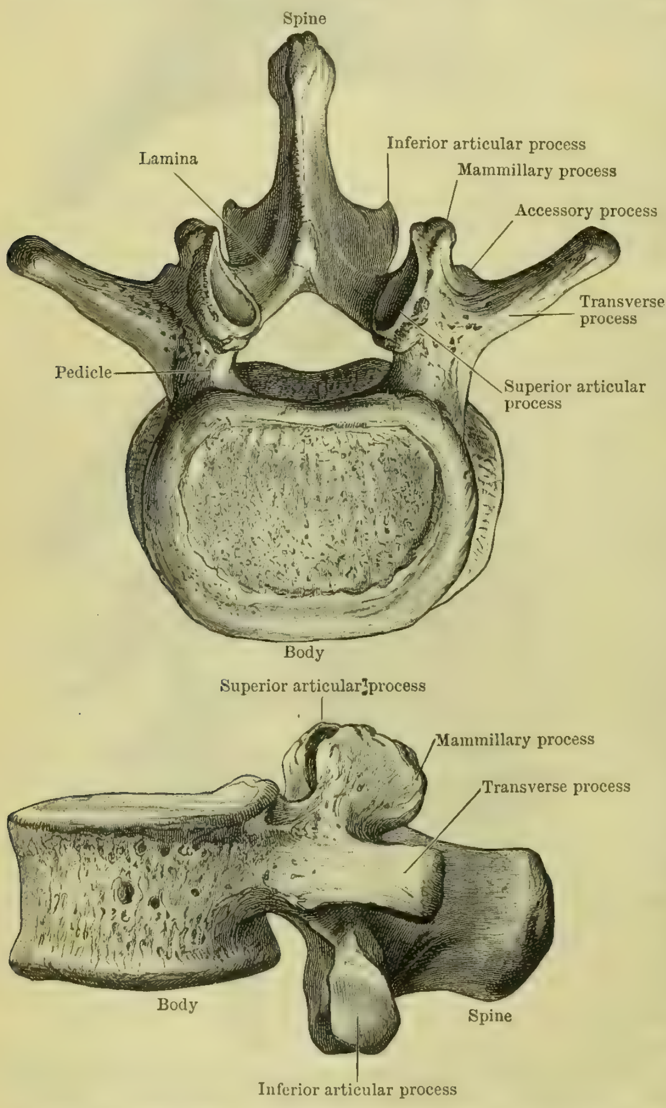


Fig. 61.—Third Lumbar Vertebra from Above, and from the Left Side.

The **body** is kidney-shaped in outline, and of large size. The transverse diameter is usually about a half greater than the antero-posterior width. The anterior thickness is slightly greater than the posterior, being thus adapted to the anterior convex curve of the column in this region. The **pedicles,** directed horizontally backwards, are short and stout; the superior notches are shallow, but deeper than in the dorsal region; the inferior grooves are deep. The **laminæ** are broad, and nearly vertical, sloping but slightly. They support on their lower margins the inferior articular processes. The **spinal foramen** is large and triangular.

The **spinous processes,** spatula shaped, with a thickened posterior margin, project backwards and slightly downwards. The **transverse processes,** more slender than in the dorsal region, pass horizontally outwards, with a slight backward inclination. Arising from the junction of the pedicles with the laminæ in the higher members of the series, they tend to advance so as to become fused with the outer side of the pedicle and back of the body in the two lower lumbar vertebræ. In these latter vertebræ the superior intervertebral groove is carried obliquely across the upper surface of the base of the transverse process. The transverse processes lie in line with the external tubercles of the lower thoracic vertebræ, with which they are serially homologous, and are to be regarded as representing the costal element. Placed on their base posteriorly, and just external to and below the superior articular processes, are the small **accessory tubercles** (processus accessorii) which are in series with the inferior tubercles of the lower thoracic vertebræ. The

superior articular processes are stout, oval, curved plates of bone, fused in front with the pedicles and laminæ, and having their concave articular surfaces vertical and in-turned. Externally, and on their posterior edge, the bone rises in the form of an elongated oval tubercle, the **mammillary process** (processus mammillaris); these are in correspondence with the superior tubercles of the lower thoracic transverse processes.

The **inferior articular processes** lie on either side of the root of the spinous process supported on the inferior margin of the laminæ. Their articular surfaces, oval in outline, convex from side to side, and plane from above downwards, are out-turned. The inferior articular processes are much closer together than the superior; so that when the vertebræ are articulated the superior articular processes of the lower vertebra embrace the inferior articular processes of the higher vertebra.

The **fifth lumbar vertebra** is characterised by the size of its body, which is the largest of all the vertebræ. Further, the under surface of the body is cut away at the expense of its posterior part: hence the thickness of the centrum in front much exceeds that of the vertical diameter behind. The **transverse process** is pyramidal in form, and stouter than those of the other lumbar vertebræ. It arises by a broad base from the side of the back of the body, as well as from the pedicle, and is directed outwards and a little backwards and upwards. Its upper surface is slightly grooved by the superior intervertebral notch. A deep notch separates it posteriorly from the superior articular processes, which are less in-turned than in the other members of the series, their articular surfaces being directed more backwards than inwards, and displaying less concavity. The inferior articular processes are further apart than is the case with the other members of the series, they lie in line with the superior. The spinous process is shorter and narrower than the other lumbar spines, particularly so in the female.

Variations.—The mammillary and accessory processes are sometimes unduly developed. The neural arch of the fifth lumbar vertebra is occasionally interrupted on either side by a synchondrosis which runs between the upper and lower articular processes. In macerated specimens the two parts of the bone are thus separate and independent. The anterior includes the centrum, together with the pedicles, transverse and superior articular processes; the posterior comprises the inferior articular processes, the laminæ, and the spine.—Turner (*Challenger Reports*, vol. xvi.).

THE FALSE OR FIXED VERTEBRÆ.

The Sacrum.

The **sacrum** (os sacrum), of roughly triangular shape, is formed by the fusion, normally, of five vertebræ. The **anterior surface** of the bone is slightly hollow from side to side and concave from above downwards, the curve being usually most pronounced opposite the third sacral segment. The central part corresponds to the bodies of the sacral vertebræ, the lines of fusion of which are indicated by a series of four parallel ridges which cross the central part of the bone at gradually diminishing intervals from above downwards; externally, these ridges disappear on either side on the inner walls of the four **anterior sacral foramina** (foramina sacralia anteriora). The size of these holes decreases from above downwards. The upper and under border of each foramen is formed by a stout bar of bone, of which there are five on each side, corresponding in number with the vertebræ present. These unite externally so as to form the **lateral mass** (pars lateralis), and thus enclose the foramina to the outer side, though here the edge is not abrupt, but sloped so as to pass gradually into the canal. The large anterior divisions of the sacral nerves pass through these foramina and occupy the shallow grooves. The bone is broadest across the first sacral vertebra, tends to narrow opposite the second, and again usually increases in width opposite the third. When this condition is well marked, the edge has a notched appearance (sacral notch) which assists in the interlocking of the sacro-iliac joint. The surface of bone between and external to the first, second, third, and fourth foramina affords attachment to the fibres of origin of the pyriformis, whilst on the edge external to and below the fourth foramen the coccygeus is inserted.

The **posterior surface** is rough and irregular. Convex from above downwards it displays mesially a **crest** (crista sacralis media) whereon are seen four elongated tubercles—the spines of the upper four sacral vertebræ. External to these the bone forms a groove—the **sacral groove**—the floor of which is made up of the confluent laminæ of the corresponding vertebræ. In line with the intervals between the spines, and wider apart above than below, another series of tubercles is to be seen. These are due to the fusion of the **articular processes** of the sacral vertebræ, and together they form faint irregular ridges on the bone (cristæ sacrales articulares). Normally, the spine of the lowest sacral segment is absent, and the laminæ do not coalesce mesially, thus leaving a gap in which the spinal canal is exposed (hiatus sacralis); whilst inferiorly the tubercles corresponding to the inferior articular

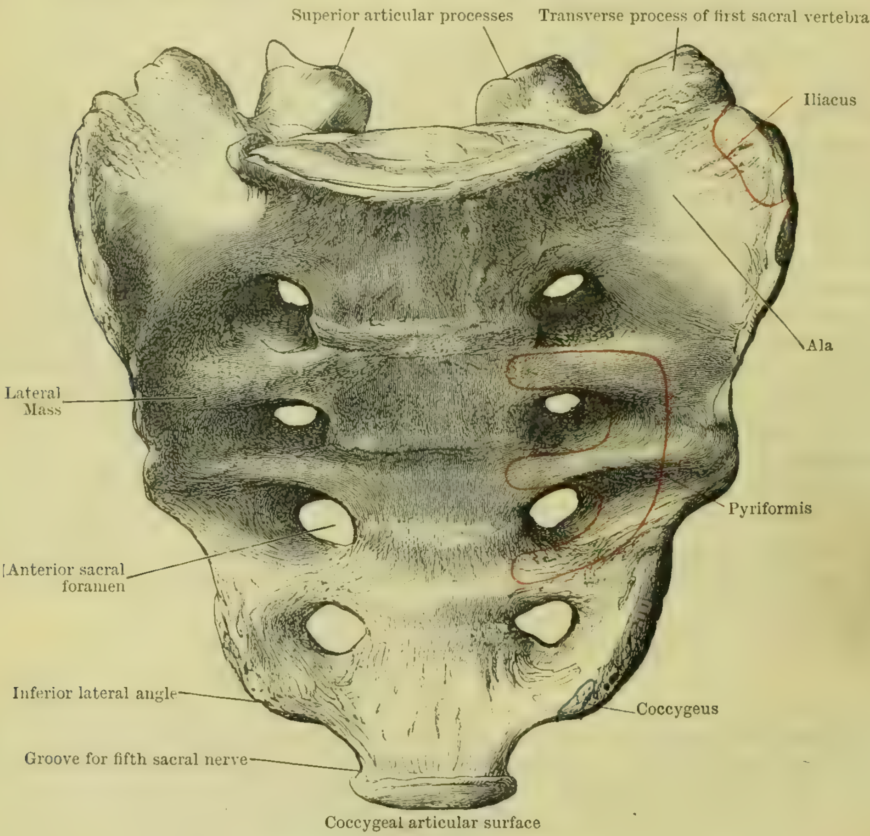


FIG. 62.—THE SACRUM (anterior view).

processes of the last sacral vertebra form little down-projecting processes—the **sacral cornua** (cornua sacralia)—by means of which the sacrum is in part united to the coccyx. Just wide of the articular tubercles are the **posterior sacral foramina** (foramina sacralia posteriora), for the transmission of the posterior divisions of the sacral nerves. These are in correspondence with the anterior foramina, so that a probe can be passed directly through both openings; but it is to be noted that the posterior are much smaller, and their margins much sharper, than is the case with the anterior. The surface of the lateral mass external to the posterior sacral foramina is rough and irregular, owing to the presence of four more or less elevated tubercles, which constitute the lateral ridges on either side of the bone (cristæ sacrales laterales), and which are serially homologous with the true transverse processes of the lumbar vertebræ.

The posterior surface of the bone furnishes an extensive surface for the origin of the erector spinæ muscles, whilst the edge of the bone external to the third and fourth foramen gives attachment to the gluteus maximus.

The **base** of the bone displays features more in accordance with a typical

vertebra. Centrally and in front is placed the **body**, the upper surface of which articulates with the last lumbar vertebra through the medium of an intervertebral disc. The anterior margin is thin and projecting, overhanging the general concavity of the front of the bone, and forming what is called the **promontory** (promontorium). Behind the body, the spinal canal, of triangular form with slightly appressed sides, is seen, whilst posteriorly is the short spinous process forming the highest tubercle of the median crest. Spreading out from the sides, and partly from the back of the body on either side, is a fan-shaped mass of bone, the upper surface of which is slightly concave from side to side, and convex from above and behind downwards and forwards. This, the **ala** (ala sacralis), corresponds to the thick upper border of the **lateral mass**, and is formed, as will be explained hereafter, by elements

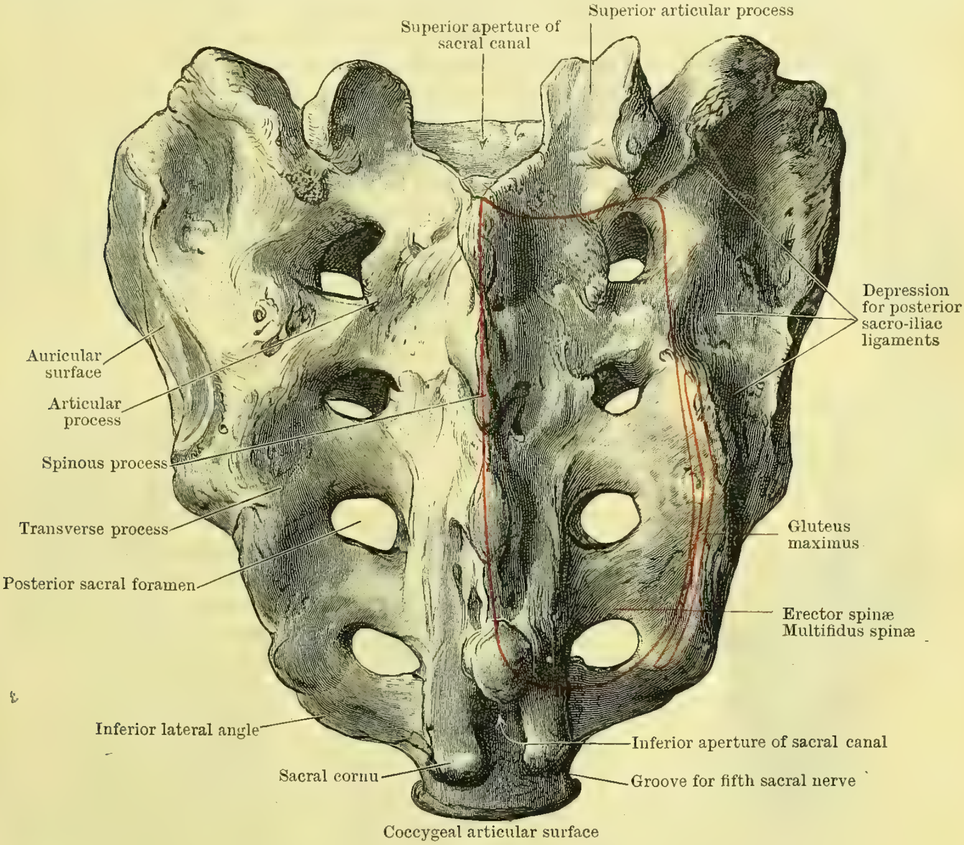


FIG. 63.—THE SACRUM (posterior view).

which correspond to the pedicles and transverse processes of the sacral vertebræ, together with superadded structures—the sacral ribs. The external margin of the lateral mass, as seen from above, is sharp and outwardly convex, terminating behind in a prominent tubercle—the highest of the series of elevations seen on the posterior surface of the bone, which have been already described as serially homologous with the true transverse processes of the lumbar vertebræ. Fused with the back of each lateral mass, and separated from it externally by a narrow but deep notch, is the **superior articular process.** This supports a vertical articular surface, which is of circular or oval form, and concave from side to side, having a general direction backwards and a little inwards.

The borders of the bone are thick above, where they articulate with the ilia, thin and tapering below, where they furnish attachments for the powerful sacro-sciatic ligaments. The **iliac articular surfaces** are described as auricular in shape (facies auriculares), and overlie the lateral masses formed by the first three sacral vertebræ, though this arrangement is liable to considerable variation. Behind the auricular surface, the bone is rough and pitted by three distinct depressions for the

attachment of the strong sacro-iliac ligaments. Inferiorly, the edge formed by the lateral masses of the fourth and fifth sacral vertebræ becomes gradually thinner, and at the **inferior lateral angle** changes its direction and sweeps inwards towards the body of the fifth sacral segment.

The **apex**, or lower end of the sacrum, is formed by the small oval body of the fifth sacral vertebra, which articulates with the coccyx.

The **sacral canal** follows the curve of the bone; more or less triangular in shape above, it becomes appressed and flattened below. Inferiorly, its posterior wall is deficient owing to the imperfect ossification of the laminæ of the fifth, and, it may be, of the fourth sacral segments. Passing obliquely outwards and downwards from this canal into the lateral masses on either side are the four pairs of intervertebral foramina, each of which is connected externally with a V-shaped canal which terminates in front and behind in the anterior and posterior sacral foramina. The hinder limb of the V is shorter and narrower than the anterior.

The female sacrum is proportionately broader than the male. Its curves are liable to great individual variation, though the absolute depth of the curve is less than in the male.

Variations.—The number of sacral segments may be increased to six or reduced to four (see p. 87). Transition forms are occasionally met with in which the first sacral segment displays on one side purely sacral characters, *i.e.* it articulates with the innominate bone, whilst on the opposite side it may present all the features of a lumbar vertebra. Through deficiency in the development of the laminæ, the neural canal may be exposed throughout its entire length, or to a greater extent than is normally the case. (Paterson, *Roy. Dublin Soc. Scientific Trans.* vol. v. Series II.)

Coccyx.

The **coccyx** consists of four—sometimes five, less frequently three—rudimentary vertebræ, which tend to become fused. The **first piece** is larger than the others; it has an oval hollow facet on its upper surface, which articulates with the body of the last sacral segment. Posteriorly, two processes, **cornua coccygea,** which lie in series with the articular processes of the sacrum, extend upwards and unite with the sacral cornua, thus bridging over the notch for the exit of the fifth sacral nerve, and converting it into a foramen, the last of the intervertebral series.

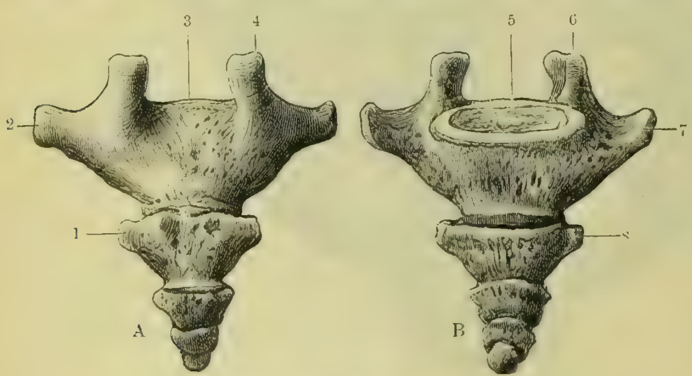


Fig. 64.—The Coccyx.

A. Posterior Surface. B. Anterior Surface.

1. Transverse process. 2. Transverse process. 3. Sacrum. 4. Cornu. 5. Sacrum. 6. Cornu. 7. Transverse process. 8. Transverse process.

From the outer side of the body projects a rudimentary **transverse process** which may, or may nôt, unite with the sacrum close to the lower lateral angle; in the latter case a fifth anterior sacral foramen is enclosed. Inferiorly, the body of the bone articulates with the succeeding vertebra. The **second coccygeal vertebra** displays slight traces of a transverse process and the rudiments of pedicles. The following segments are mere rounded or oval-shaped nodules of bone.

Fusion between the lower elements occurs normally in middle life, whilst union between the first and second segments occurs somewhat later. It is not unusual, however, to find that the first coccygeal vertebra remains separate from the others. Though very variable, as a rule, fusion occurs more commonly in the male, and at an earlier age than in the female.

From the posterior surface of the coccyx the gluteus maximus arises. To its external borders are attached the coccygei and levatores ani muscles, and from its tip spring the fibres of the sphincter ani.

VERTEBRAL COLUMN AS A WHOLE.

When all the vertebræ are articulated together, the resulting column displays certain characteristic features. The division of the column into a true or movable part, comprising the members of the cervical, thoracic, and lumbar series, and a false or fixed portion, including the sacrum and coccyx, can now be readily recognised. The vertebræ are so disposed that the centra or bodies form an interrupted column of solid parts in front, which constitutes the axis of support for the head and trunk; whilst the neural arches behind form a canal for the lodgment and protection of the spinal cord and its membranes. In the movable part of the column both the anterior supporting axis and the neural canal are liable to changes in their direction owing to the movements of the head and trunk. Like the bodies and neural arches the spinous and transverse processes are also superposed, and fall in line, forming three series of interrupted ridges—one (the spinous) placed centrally, the others (the transverse) placed laterally. In this way two **vertebral grooves** are formed which lie between the central and lateral ridges. The floor of each groove is formed by the laminæ and articular processes, and in these grooves are lodged the muscles which serve to support and control the movements of the column.

Further, the column so constituted is seen to display certain **curves** in an antero-posterior direction. These curves are, of course, subject to very great variation according to the position of the trunk and head, and can only be satisfactorily studied in a fresh specimen; but if care be exercised in the articulation of the vertebræ, the following characteristic features may be observed, assuming, of course, that the column is erect and the head so placed that the axis of vision is directed towards the horizon. There is a forward curve in the cervical region, which gradually merges with the backward thoracic curve; this becomes continuous below with an anterior convexity in the lumbar region, which ends more or less abruptly at the union of the fifth lumbar with the first sacral vertebra, where the sacrum slopes suddenly backwards, causing the column to form a marked projection—the **sacro-vertebral angle.** Below this, the anterior concavity of the front of the sacrum is directed downwards as well as forwards. Of these four curves, two—the thoracic and sacral—are primary, they alone exist during fœtal life; whilst the cervical and lumbar forward curves only make their appearance after birth—the former being associated with the extension and elevation of the head, whilst the latter is developed in connexion with the use of the hind limb in the hyper-extended position, which in man is correlated with the assumption of the erect posture; this curve, therefore, only appears after the child has begun to walk. For these reasons the cervical and lumbar curves are described as secondary and compensatory.

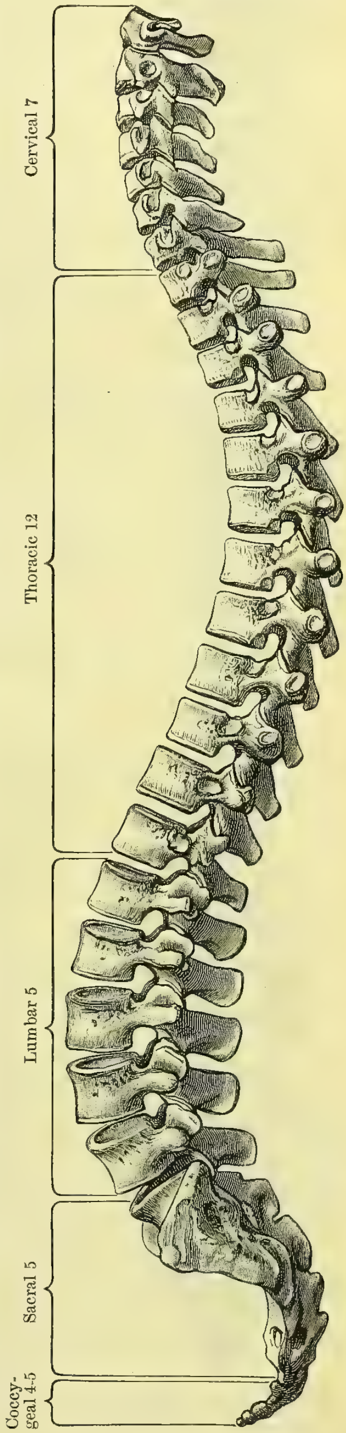


Fig. 65.—Vertebral Column from the Left Side.

Not infrequently there is a slight **lateral curvature** in the dorsal region, the convexity of the curve being usually directed towards the right side. This may be associated with a greater use of the muscles of the right upper limb, or may depend on the pressure exercised by the upper part of the thoracic aorta on the vertebræ of the dorsal region, thus causing a slight lateral displacement. Above and below this curve there are slight compensatory curves in the opposite direction.

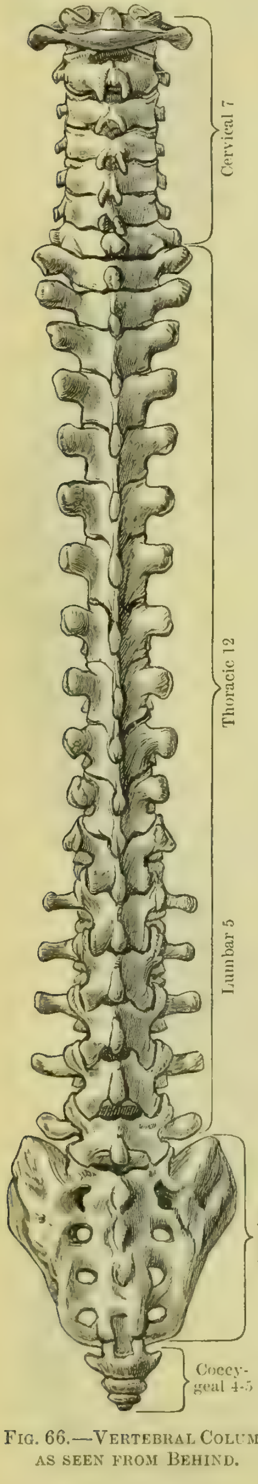


FIG. 66.—VERTEBRAL COLUMN AS SEEN FROM BEHIND.

The line which unites the tips of the spines is not a repetition of the curves formed by the bodies. This is due to the fact that the length and direction of the spines vary much in different regions; thus in the neck, with the exception of the second, sixth, and seventh, the spines are all short (absent in the case of the atlas). In the thoracic region the spines, though long, are obliquely placed—a circumstance which much reduces their prominence; that of the seventh thoracic vertebra is usually the longest and most slanting. Below this point the length of the spines gradually decreases, and their position more nearly approaches the horizontal. In the loins, the spines have all a slight downward direction.

Taken as a whole, the spines of the movable vertebræ in man have a downward inclination—a character which he shares with the anthropoid apes, and a few other animals. This character serves to distinguish his column from those of lower mammals in which the spines of the lumbar vertebræ are directed headwards towards the "centre of motion," which is usually situated near the hinder extremity of the thorax, where a vertebra is placed the direction of whose spine is vertical; this vertebra is often referred to as the **anticlinal vertebra.**

The spines of the upper three or four sacral vertebræ form an osseous ridge with interrupted tubercles. The ridge formed by the vertebral spines is an important determinant of the surface form, as it corresponds to the median furrow of the back, and here the individual spines may be felt and counted from the seventh cervical down to the sacral region. This is best done when the back is well bent forwards.

As viewed from the front, the vertebral bodies increase in width from the second cervical to the first thoracic; thence a reduction in breadth takes place to the level of the fourth thoracic, below which there is a gradual increase in their transverse diameters until the sacrum is reached. Here a rapid reduction in width takes place, terminating inferiorly in the nodules of the coccyx.

The transverse processes of the atlas are wide and outstanding. The succeeding four cervical vertebræ have transverse processes of nearly equal width; the seventh, however, displays a marked increase in its transverse diameter, and is about equal in width to the first thoracic vertebra. Below this a gradual and regular diminution in width characterises the transverse processes of the thoracic vertebræ, until in the case of the eleventh and twelfth they are merely represented by the small external tubercles. In the lumbar region the transverse processes again appear outstanding, and of nearly equal length.

The transverse diameter of the lateral mass of the first sacral vertebra forms the widest part of the column. Below this a decrease in width occurs until the level of the third sacral segment is reached, at which point the transverse diameter is somewhat abruptly diminished, a reduction in width which is further suddenly accentuated opposite the fifth sacral segment.

As viewed from the side, the bodies display a gradual increase in their antero-posterior width until the second lumbar vertebra is reached, below which this diameter is slightly reduced. In the sacral region the reduction in this diameter is great in the first and second sacral segments, more gradual and less marked in the last three segments.

The facets for the heads of the ribs in the upper thoracic region lie on the sides of the bodies; those for the tenth, eleventh, and twelfth are placed further back on the pedicles.

The **intervertebral foramina** increase in size from above downwards on the movable part of the column, being largest in the lumbar region. In the sacral region they decrease in size from above downwards. In the cervical region the two highest cervical nerves pass out behind the articular processes of the atlas and axis, and lie, therefore, behind the corresponding transverse processes of these vertebræ. The succeeding cervical nerves pass out through the intervertebral foramina which are placed between the transverse processes and in front of the articular processes. In the thoracic and lumbar vertebræ the intervertebral foramina lie in front of both the articular and transverse processes. The arrangement of these foramina in the sacrum has been already sufficiently explained.

The **neural canal** for the lodgment of the spinal cord and its meninges is largest in the cervical and lumbar regions, in both of which it assumes a triangular form; whilst it is narrow and circular in the thoracic region. These facts are correlated with the movements of the column which are most free in those regions where the canal is largest, *i.e.* the neck and loins.

The **average length** of the vertebral column is from 70 to 73 centimetres, or from $27\frac{1}{2}$ to $28\frac{3}{4}$ inches. Of this the cervical part measures from 13 to 14 cm.; the thoracic, 27 to 29 cm.; lumbar, 17 to 18 cm.; and the sacro-coccygeal, 12 to 15 cm. The individual differences in the length of the column are less than one might expect, the variation in height of different individuals being often largely dependent on the length of the lower limbs. In the female the average length of the column is about 60 centimetres, or $23\frac{3}{4}$ inches, and the curve in the lumbar region is usually more pronounced.

Architecture.—The vertebræ are formed of spongy bone confined within a thin and dense envelope. In the bodies the arrangement of the cancellous tissue, which is traversed by venous channels, is such as to display a vertical striation with lamellæ arranged horizontally. The external, superior, and inferior walls are very thin—that directed to the neural canal being usually thicker and denser than the others. In the pedicles and roots of the transverse processes the cancellous tissue is much more open. The outer envelope is much thicker where it bounds the neural ring, and where it forms the bottom of the superior and inferior intervertebral notches. In the laminæ the spongy tissue is confined between two compact layers, of which that directed to the spinal canal is the thicker. In the spinous processes the upper edge is always the more compact.

Variations.—Numerical Variations of the Column as a Whole.—Increase in the number of vertebral segments is usually due to differences in the number of the coccygeal vertebræ; these may vary from four—which may be regarded as the normal number—to six. The number of presacral or movable vertebræ is normally 24 (7 C, 12 D, and 5 L). This number may be increased by the intercalation of a segment either in the thoracic or lumbar region without any alteration in the number of the sacral or coccygeal elements: thus we may have 7 C, 13 D, and 5 L, or 7 C, 12 D, and 6 L, or may be reduced by the disappearance of a vertebral segment—thus, 7 C, 12 D, and 4 L. Such an arrangement presupposes developmental errors either of excess or default in the segmentation of the column. On the other hand, the total number of vertebral segments remaining the same (24 or 25), we may have variations in the number of those assigned to different regions due to the addition of a vertebral segment to one, and its consequent subtraction from another region. Thus, in the 24 presacral vertebræ, in cases of the occurrence of cervical ribs the formula is rearranged thus—6 C, 13 D, and 5 L, or, in the case of a thirteenth rib being present, the formula would be 7 C, 13 D, 4 L, as happens normally in the gorilla and chimpanzee. Similarly, the number of the presacral vertebræ (24) may be increased by the withdrawal of a segment from the sacral region—7 C, 12 D, 6 L, and 4 S—or diminished by an increase in the number of the sacral vertebræ, as in the formula 7 C, 12 D, 4 L, and 6 S. Increase in the number of sacral segments may be due to fusion with a lumbar vertebræ, or by the addition of a coccygeal element: the latter is more frequently the case. This variability in the constitution of the sacrum is necessarily correlated with a shifting backwards and forwards of the pelvic girdle along the vertebral column. Rosenburg considers that the 26th, 27th, and 28th vertebræ are the primitive sacral segments, and that the sacral characters of the 25th vertebræ (the first sacral segment in the normal adult column) are only secondarily acquired. He thus supposes that during development there is a forward shifting of the sacrum and pelvic girdle, with a consequent reduction in the length of the presacral portion of the column. This view is opposed by Paterson (*Roy. Dublin Soc. Scientific Trans.* vol. v. Ser. II.), who found that ossification took place in the alæ of the 25th vertebra (first adult sacral segment) before it made its appear-

ance in the alæ of the 26th vertebra. He thus assumes that the alæ of the 25th vertebra may be regarded as the main and primary attachment with the ilium. His conclusions, based on a large number of observations, are at variance with Rosenburg's views, for, according to his opinion, liberation of the first sacral segment is more common than assimilation with the fifth lumbar vertebra, and assimilation of the first coccygeal vertebra with the sacrum is more common than liberation of the fifth sacral, thus leading to the inference that the sacrum tends to shift backwards more often than forwards.

Ossification of the Vertebræ.—The vertebræ are developed by ossification of the cartilage which surrounds the notochord and which passes backwards over the sides of the neural canal. The centres for the bodies first appear in the lower thoracic vertebræ about the tenth week. An oval nucleus develops in each body. At first it is placed dorsal to the notochord, but subsequently surrounds and causes the disappearance of that structure. Occasionally, however, the primitive centre appears to be formed by the coalescence of two primary nuclei. Support is given to this view by the occasional occurrence of vertebræ in which the body is developed in two lateral halves, or in cases where only one-half of the body persists (Turner); normally, however, it is impossible to make out this division. From these single nuclei the bodies are developed, the process extending up and down the column until, by the fifth month, all the centra possess ossific deposits, except the coccygeal segments. About the seventh week a single centre appears in the

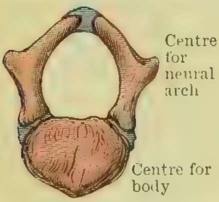


Fig. 67.—Ossification of Vertebræ.

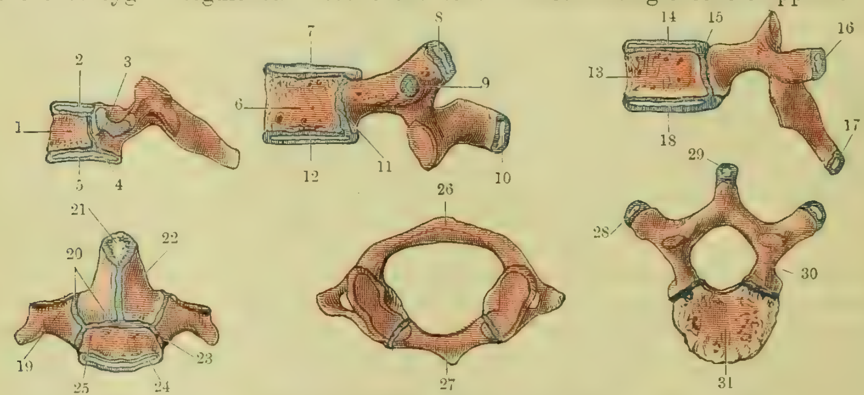


Fig. 68.—Ossification of Vertebræ.

Cervical vertebra.

1. Centre for body.
2. Superior epiphysial plate.
3. Anterior bar of transverse process developed by lateral extension from pedicle.
4. Neuro-central synchondrosis.
5. Inferior epiphysial plate.

Lumbar vertebra.

6. Body.
7. Superior epiphysial plate.
8. Epiphysis for mammillary process.
9. Epiphysis for transverse process.
10. Epiphysis for spine.
11. Neuro-central synchondrosis.
12. Inferior epiphysial plate.

Dorsal vertebra.

13. Centre for body.
14. Superior epiphysial plate, appears about puberty; unites at 25th year.
15. Neuro-central synchondrosis does not ossify till 5th or 6th year.
16. Appears at puberty; unites at 25th year.
17. Appears at puberty; unites at 25th year.
18. Appears about 6th week.

Axis.

19. Centre for transverse process and neural arch; appears about 8th month.
20. Synchondroses close about 3rd year.
21. Centre for summit of odontoid process; appears 3rd to 5th year, fuses 8th to 12th year.
22. Appears about 5th or 6th month; unites with opposite side 7th to 8th month.
23. Synchondrosis closes from 4th to 6th year.
24. Inferior epiphysial plate; appears about puberty, unites about 25th year.
25. Single or double centre for body; appears about 5th month.

Atlas.

26. Posterior arch and lateral masses developed from a single centre on either side, which appears about 7th week.
27. Anterior arch and portion of superior articular surface developed from single or double centre, appearing during 1st year.

Dorsal vertebra.

28. Epiphysis for transverse process; appears about puberty, unites about 25th year.
29. Epiphysis appears about puberty; unites about 25th or 27th year.
30. Centre for body on either side of neural arch; appears about 6th or 7th week, the laminæ unite from birth to 15th month.
31. Centre for body; appears about 6th week, unites with neural arch from 5th to 6th year.

neural arch on either side. These commence first to ossify in the upper cervical region and extend rapidly downwards throughout the column. They first appear near the bases

of the superior articular processes, and extend backwards into the laminæ, outwards into the transverse processes, and forwards into the pedicles. These latter project anteriorly, and form a considerable portion of the postero-lateral aspects of the body, from which, however, they are separated by a cartilaginous strip—the neuro-central synchondrosis—which does not entirely disappear until about the fifth or sixth year. It is important to note that in the thoracic region the costal facets lie behind the neuro-central synchondrosis, and are therefore borne on the lateral aspects of the pedicles. Fusion of the laminæ in the mesial plane behind begins, after birth, in the lumbar region and extends upwards, so that by the fifteenth month or thereabouts the arches in the cervical region are completed behind. In the sacral region ossification is slower, the spinal canal not being enclosed till the seventh to the tenth year. The spinous processes are cartilaginous at birth, but these become ossified by the extension into them of the bony laminæ.

At puberty certain **secondary centres** or **epiphyses** make their appearance; these are five in number. One caps the summit of the spinous process, except in the cervical region. A single epiphysis on either side appears at the extremity of the transverse process, and in the thoracic region assists in forming the articular surface for the tubercle of the rib. Two epiphysial plates are formed—one for the upper, and the second for the lower surface of the body, including also that part which lies behind the neuro-central synchondrosis and formed by the pedicle; from these the thickened circumference of both upper and lower aspects of the body are derived. Fusion of these centres with the rest of the bone is not complete till the twenty-fifth year.

In the cervical region independent centres are described as occurring in the anterior roots of the transverse processes of the sixth and seventh vertebræ. These correspond to the costal element, and may occasionally persist in the form of cervical ribs. Elsewhere they are formed by lateral extensions from the pedicle.

In the lumbar region the transverse process of the first lumbar vertebra is occasionally associated with an independent costal centre, which may blend with it, or persist as a lumbar rib. The mammillary processes are derived from separate epiphyses. The neural arch of the fifth lumbar vertebra is occasionally developed from two centres on either side, as is demonstrated by the fact that the arch is sometimes divided by a synchondrodial joint running obliquely across between the superior and inferior articular processes on either side. (See *ante*, p. 81; also *Fortschritte auf dem Gebiete der Röntgenstrahlen.* Ergänzungsheft i.; "die Entwickelung des menschlichen Knochengerüstes während des fötalen Lebens," von Lambertz.)

Atlas.—The lateral masses and posterior arch are developed from two centres—one on either side—which correspond with the centres from which the neural arches of the other members of the series are developed. These make their appearance about the seventh week, and do not unite posteriorly till after the third year. Their point of union is sometimes preceded by the formation of a distinct spinal nucleus (Quain). The anterior arch is developed from centres variously described as single or double, which appear in one of the hypochordal arches of cartilage described by Froriep (*Arch. f. Anat. u. Physiol.*, *Anat. Abth.* 1886) which here persists. In this cartilage, ossification commences during the first year of life. Union with the lateral masses is delayed till six or eight years after birth. The external extremities of the anterior arch assist in forming the fore part of the superior articular processes.

The **Axis** ossifies from five primitive centres. Of these, two—one on either side—appear about the seventh week, and form the articular and transverse processes, together with the laminæ and spine. One, or it may be two, nuclei appear in the lower part of the body about the fifth month. The upper part of the body, including a small part of the superior articular process, and the base of the odontoid process, are developed from two laterally-placed nuclei which appear shortly after, and fuse together at the seventh or eighth month, so that at birth the bone consists of four pieces. Fusion between these parts takes place in the following order:—The odontoid unites with the body and lateral parts about the third or fourth year; union between the two lateral portions posteriorly and the body and lateral parts in front, is complete at from four to six years.

The summit of the odontoid process is developed from a separate centre, occasionally double, which appears from the third to the fifth year, and fuses with the rest of the bone from the eighth to the twelfth year. About puberty an annular epiphysis is developed on the under surface of the body, with which it is completely united during the twentieth to the twenty-fifth year. Some authorities state that a few granules between the base of the odontoid and the upper surface of the body represent the superior epiphysial plate; but as fusion between the odontoid and the body occurs before the time for the appearance of these secondary epiphysial plates, this can hardly be regarded as correct. The line of

fusion of the odontoid with the body is defined by a small disc of cartilage which persists within the substance of the bone till an advanced period of life.

A pair of epiphyses placed over the tubercles of the spine, if not always present, are at least frequent.

Sacrum.—Each of the sacral segments is ossified from three centres: one for the body, and two for the neural arch—that for the body, which makes its appearance in the first three sacral vertebræ about the end of the third month, about the fifth to the eighth month for the last two segments. From the two centres for the neural arches, which make their appearance about the fifth or sixth month in the higher segments, the laminæ, articular processes, and the posterior half of the alæ on either side are developed. The spinal canal is not enclosed till the seventh to the tenth year, the laminæ usually failing to meet in the lowest segment, and occasionally, to a greater or less extent, in some of the higher segments. The anterior part of the lateral masses is developed from separate centres which represent the costal elements (Gegenbauer). These appear about the sixth to the eighth month, and may develop in relation to the upper four sacral segments; more usually they are met with in connexion with the first three, and exceptionally they may be found only in the upper two. It is by fusion of these with the posterior arches that the lateral masses which support the innominate bones are formed. The costal elements fuse about the second to the fifth year with the neural arches, prior to their union with the centra; and the segments of the lateral masses unite with each other sooner than the union of the bodies is effected. The latter only takes place after puberty by the fusion of the epiphysial plates, a pair of which make their appearance between the centra of each segment. The lower segments begin to unite together about the eighteenth year, but fusion between the first and second sacral vertebræ is not completed till the twenty-fifth year or after. In addition to the foregoing, two thin osseous laminæ are developed in the cartilage covering the outer surface of the alar mass. The upper of these overspreads the auricular surface, whilst the lower forms the sharp edge below. The extremities of the upper spinous processes are occasionally developed from independent epiphyses. On making a mesial section of an adult bone the persistence of the intervertebral discs between the centra is indicated by a series of oval cavities.

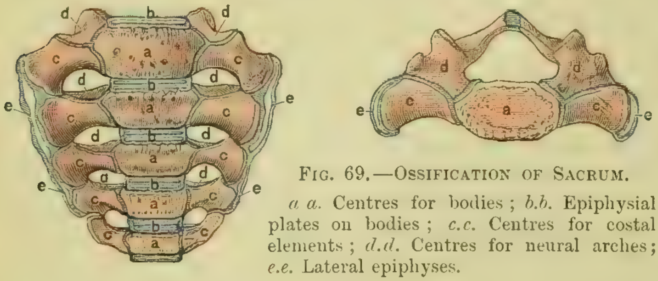


Fig. 69.—Ossification of Sacrum.

a a. Centres for bodies; *b.b.* Epiphysial plates on bodies; *c.c.* Centres for costal elements; *d.d.* Centres for neural arches; *e.e.* Lateral epiphyses.

Coccygeal Vertebræ.—These are cartilaginous at birth. Each has a separate centre; the first appears from the first to the fourth year, the second from the sixth to the tenth year, the third and fourth segments at or about puberty. Secondary centres, for the coccygeal cornua and epiphysial plates for the bodies are also described. Fusion of the various segments begins below and proceeds upwards, but is liable to great individual variation. In advanced life the coccyx is often ossified to the sacrum.

SERIAL HOMOLOGIES OF THE VERTEBRÆ.

It is a self-evident fact that the vertebral column consists of a number of segments or vertebræ all possessing some characters in common. These vertebræ or segments undergo modifications according to the region they occupy and the functions they are called upon to serve, so that their correspondence and identity is thereby obscured. There is no difficulty in recognising the correspondence of the bodies and neural arches throughout the column. According to some anatomists the neural arch is the more primitive element in the formation of a vertebra, whilst others hold that the centra are the foundation of the column. Be that as it may, we find that in the higher vertebrates, at least, the bodies are the parts which most persist. They are, however, subject to modifications dependent on their fusion with one another. This occurs in the cervical part of the column where the centrum of the first cervical or atlas vertebra has for functional reasons become fused with the body of the second or axis vertebra to form the odontoid process of that segment. For similar reasons, and in association with the union of the girdle of the hind-limb with the column, the bodies of the vertebræ which correspond to the sacral segment become fused together to form a solid mass. In the terminal portion of the caudal region the centra alone represent the vertebral segments.

As regards the neural arch, this in man becomes deficient in the lower sacral region, and absent altogether in the lower coccygeal segments. The spinous processes are absent in the case of the

first cervical, lower sacral, and all the coccygeal vertebræ, and display characteristic differences in the cervical, thoracic, and lumbar regions, which have been already described. The articular processes (zygapophyses) are secondary developments, and display great diversity of form, determined by their functional requirements. It is noteworthy that, in the case of the upper two cervical vertebræ, they are so disposed as to lie in front of the foramina of exit of the upper two spinal nerves, and by this arrangement the weight of the head is transmitted to the solid column formed by the vertebral bodies, and not on to the series of neural arches. It is in regard to the homology of the transverse processes, so called, that most difficulty arises. In the thoracic region they can best be studied in their simplest form; here the ribs—which Gegenbauer regards as a differentiation from the inferior or hæmal arches, in opposition to the view advanced by others that they are a secondary development from the fibrous intermuscular septa—articulate with the transverse processes and bodies of the thoracic vertebræ through the agency of the tubercular (diapophysis) and capitular (parapophysis) processes respectively, the latter being placed, strictly speaking, on the neural arch behind the line of the neuro-central synchondrosis.

An interval is thus left between the neck of the rib and the front of the transverse process; this forms an arterial passage which corresponds to the vertebrarterial canal in the transverse processes of the cervical vertebræ, the anterior bar of which is homologous with the head and tubercle of the thoracic rib, whilst the posterior part lies in series with the thoracic transverse process. These homologies are further emphasised by the fact that in the case of the seventh cervical vertebra the anterior limb of the so-called transverse process is developed from an independent ossific centre, which occasionally persists in an independent form as a cervical rib.

In the lumbar region the external or transverse process is serially homologous with the thoracic ribs, though here, owing to the coalescence of the contiguous parts, there is no arterial channel between the rib element and the true transverse process, which is represented by the accessory processes (anapophysis), placed posteriorly at the root of the so-called transverse process of human anatomy. Support is given to this view by the presence of a distinct costal element in connexion with the transverse process of the first lumbar vertebra, which accounts for the occasional formation of a supernumerary rib in this region.

In the sacrum the lateral mass of the bone is made up of combined transverse and costal elements, with no intervening arterial channel. In the case of the upper three sacral segments the costal elements are largely developed, assist in supporting the ilia, and are called the true sacral vertebræ; whilst the lower sacral segments, which are not in contact with the ilia, are referred to as the pseudo-sacral vertebræ.

The anterior arch of the atlas vertebra is, according to Froriep, developed from a hypochordal strip of cartilage (hypochordal spange).

THE STERNUM.

The **sternum** or **breast bone** occupies the middle of the upper part of the thoracic wall anteriorly. It is connected laterally with the cartilages of the first seven ribs, and supports, superiorly, the clavicles. It consists of three parts, named respectively the **manubrium** or **presternum**; the **body** (corpus sterni), **gladiolus** or **mesosternum**; and the **ensiform** or **xiphoid cartilage** (processus xiphoideus) or the **metasternum**. Of these the body is formed by the fusion in early life of four segments or sternebræ.

The **manubrium,** usually separate throughout life from the rest of the bone, though occasionally fused with it, is of a flattened triangular form. The anterior surface, slightly saddle-shaped, affords attachment to the fibres of the pectoralis major and sterno-mastoid muscles. It is bounded above by a thick border, the lateral parts of which are hollowed out obliquely to form the facets (incisuræ claviculares) for the sternal ends of the clavicles; around the facets, which have an upward, outward, and slightly backward direction, the bone is faintly lipped. In the interval between these two facets there is a slight notch (incisura jugularis) which forms the floor of the characteristic hollow seen at the root of the neck anteriorly —the suprasternal notch, or pit of the neck. The lateral borders are excavated immediately below the clavicular facets for the reception of the cartilages of the first ribs. Below this, the margin of the bone slopes inwards, and is sharp, except inferiorly, where it presents a facet which supports a part of the second costal cartilage. Around this the bone is usually lipped anteriorly. The upper angles correspond to the ridge separating the clavicular facets from the first costal facets; whilst the lower angle, which may be regarded as cut across transversely, forms the surface which is united by cartilage to the body of the sternum. The anterior edge of this surface is usually prominent. The posterior aspect of the manubrium is smoother than the anterior, is pierced by numerous foramina, and is slightly concave from side to side and above downwards. Here are attached some of the fibres of the sterno-hyoid and sterno-thyroid muscles.

The **body** (corpus sterni), usually twice the length and from half to two-thirds the width of the manubrium, displays evidence of its composite nature. If the *anterior surface*, which is slightly convex from above downwards, and faintly concave from side to side, be carefully examined, three ill-marked ridges may be seen crossing it transversely; these correspond to the lines of fusion between the four primitive segments. To this surface of the bone the great pectoral muscles are extensively attached on either side of the middle line. The *lateral borders* are thick and interrupted at points corresponding to the transverse lines already mentioned by U-shaped hollows, the edges of which are more or less projecting. These are for the reception of the cartilages of the third, fourth, and fifth ribs. The *upper border* is united to the manubrium above, and forms with it an angle of variable degree—the **sternal angle** (angulus sterni). A small facet is formed at the expense of the outer extremity of this border, and in conjunction with the facet on the lower border of the manubrium forms a recess on either side, in line with the angle, into which the cartilage of the second rib fits. The *lower border* of the body is curved, and in the middle line is united with the xiphoid cartilage, whilst on either side it is pitted to receive the cartilages of the sixth and seventh ribs, the latter being in part supported by the xiphoid cartilage. The middle line of the body of the sternum anteriorly corresponds to the floor of the median surface furrow, which runs down the front of the chest in the interval between the two great pectorals. The *posterior surface* is slightly concave from above downwards, and displays faint indications of three transverse lines in correspondence with those placed anteriorly. It is in relation with the pleura and pericardium, and affords attachment at its lower extremity to the triangularis sterni muscle.

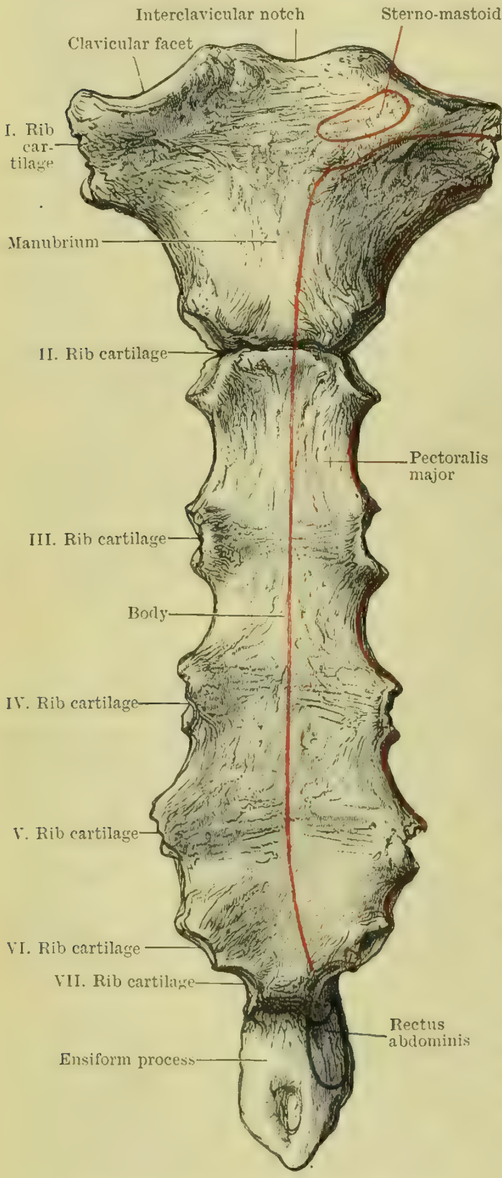


FIG. 70.—THE STERNUM (anterior view).

The **xiphi-sternum** (processus xiphoideus) displays many varieties of form and structure. It is a pointed process of cartilage, supported by a core of bone connected above with the lower end of the body of the sternum, and having its lower extremity, to which the linea alba is attached, free. It lies somewhat posterior to the plane of the anterior surface of the manubrium, and forms a floor to the V-shaped interval between the cartilages of the seventh ribs. In this way a depression is formed, the surface hollow in correspondence with which is called the pit of the stomach or **infrasternal depression.** To the sides of this process are attached the aponeuroses of the abdominal muscles, whilst posteriorly the fibres of the diaphragm and triangularis sterni muscles derive attachment from it. It remains partly cartilaginous until middle life, at which time it generally undergoes ossification, particularly at its upper part, and becomes fused with the body. Of varied form, it may be met

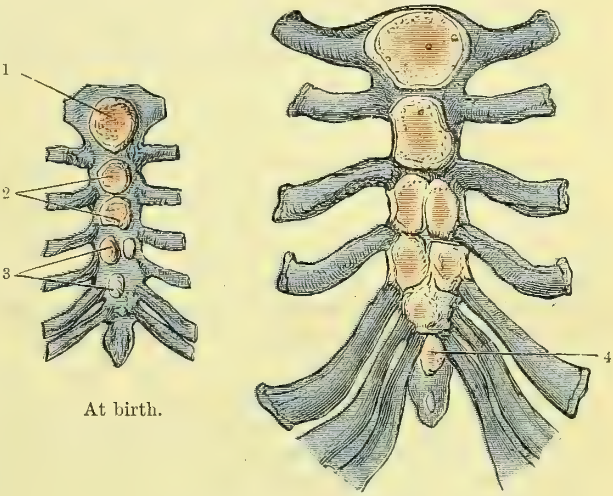
with of spatula-shape, bifid, circular, pierced in the centre, or twisted and deflected to one or other side, or turned forward.

The **sternum as a whole** is broadest above where the first rib cartilages are attached. It becomes narrow opposite the second rib cartilages, but again expands until the level of the fifth rib cartilage is reached, below which it is rapidly reduced in width and ends below in the pointed xiphoid cartilage. Its position in the body is oblique from above downwards and forwards; its axis, if prolonged upwards, would touch the column opposite the third or fourth cervical vertebra. Though liable to changes in position by the rising and falling of the chest-wall, its upper extremity corresponds to the level of the lower border of the second dorsal vertebra, whilst the lower end of the xiphoid cartilage usually falls in line with the disc between the tenth and eleventh dorsal vertebræ.

In women the sternum is usually narrower and shorter than in men, and its position less oblique.

Architecture.—It consists of large-celled spongy bone, which is highly vascular, and is contained between two layers of thin compact tissue.

Ossification. — The cartilaginous sternum, developed from the fusion mesially of two cartilaginous bands uniting the anterior extremities of the cartilages of the first eight ribs, begins to ossify about the sixth month of fœtal life. About this time a single centre appears in the manubrium; at birth this is well developed. Secondary epiphyses have been decsribed in connexion with the clavicular facets; these do not unite with the rest of the manubrium till adult life is reached. The body formed by the fusion of four segments is ossified from independent centres, either single or double, for each segment. These appear—the highest as early as the sixth month of intra-uterine life—in some cases even before the manubrium has begun to ossify (Lambertz), the lowest toward the end of full term. The common arrangement met with at birth is a single centre for the first, and double centres for each of the succeeding segments. Union between these segments occurs rather irregularly, and is liable to much variation. The fourth unites with the third segment in early childhood, the third with the second about puberty, whilst the fusion of the second with the first segment may not be complete till the twentieth or twenty-fifth year.



At birth.

At 3 years.

Fig. 71.—Ossification of the Sternum.

In this figure the second as well as the third segment of the body possesses two centres.

1. Appears about 5th or 6th month. 2. Appear about 7th month; unite from 20 to 25. 3. Appear about 8th or 9th month; III. segment unites with II. about puberty; IV. segment unites with III. in early childhood. 4. Appears about 3rd year or later.

The xiphi-sternum usually ossifies from a single centre, which may appear as early as the third year, though often very much later. The xiphi-sternum usually unites with the body about forty or fifty, and in exceptional cases osseous union between the body and manubrium may occur in advanced life.

Variations.—The sternum is liable to considerable individual variations affecting its length and direction. The majority of bones are asymmetrical, displaying irregularities in the levels of the clavicular facets. The higher costal facets may be closer together on one, usually the right side, than the other, whilst the pre-mesosternal joint is often oblique, sloping somewhat to the right. According to Birmingham, these are the result of the strain thrown on the shoulder by pressure either directly applied or through the pull of a weight carried in the hand.

Sometimes the sternum articulates with eight rib cartilages. This may happen on one or both sides, but when unilateral, much more frequently on the right side—a condition by some associated with right-handedness. It is, however, more probably a persistence of the primitive condition of the cartilaginous sternum, in which each half is connected with the anterior

extremities of the first eight costal arches. In some rare cases only six pairs of ribs articulate by means of their costal cartilages with the sternum.

Occasionally the presternum supports the first three ribs; in other words, the manubrium has absorbed the highest segment of the body. Keith has pointed out that this is the condition most commonly met with in the Gibbon, and regards its occurrence in man as a reversion to the simian type. As far as is at present known, its occurrence seems more common in the lower races. Through errors of development the sternum may be fissured throughout, due to failure of fusion of the cartilaginous hemisterna. The two ossified halves are usually widely separated above, but united together below by an arthrodial joint. The heart and pericardium are thus uncovered by the bone. Occasionally this condition is associated with ectopia cordis, under which circumstances life is rendered impossible. Through defects in ossification the mesosternum may be pierced by a hole, usually in its lower part, or through failure of fusion of the lateral centres one or more of the segments of the body may be divided longitudinally.

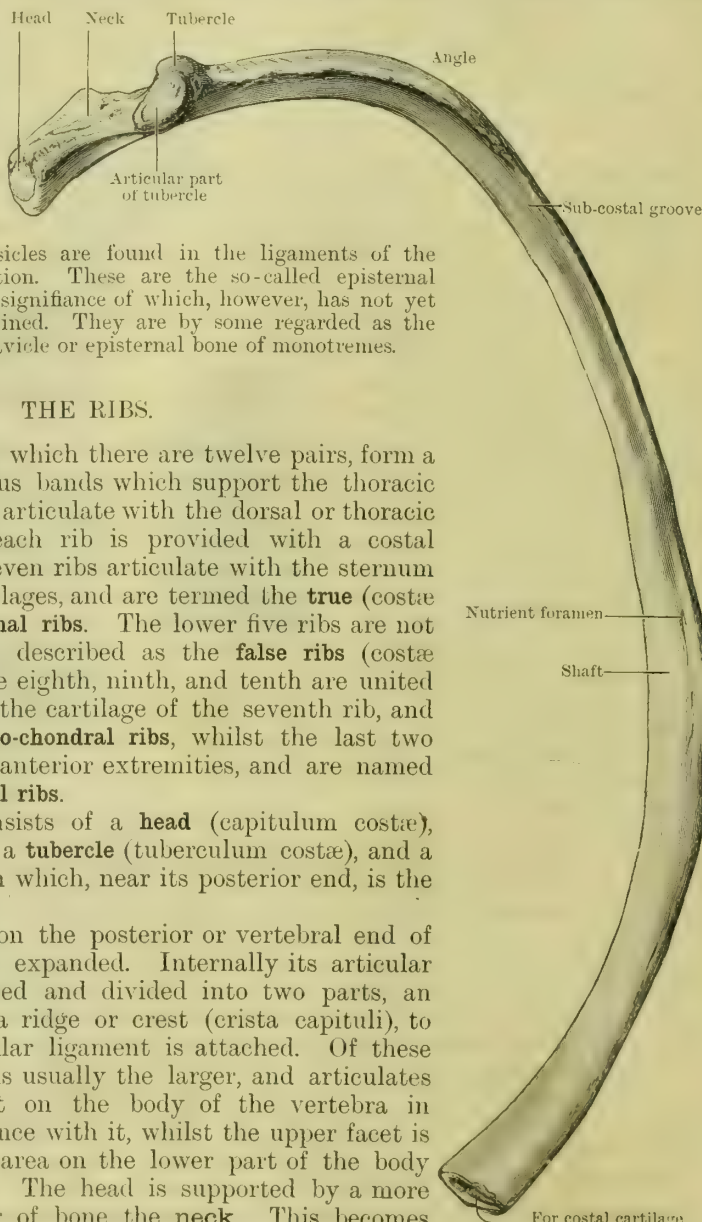


Fig. 72.—Fifth Right Rib as seen from Below.

Occasionally small ossicles are found in the ligaments of the sterno-clavicular articulation. These are the so-called episternal bones, the morphological signifiance of which, however, has not yet been satisfactorily determined. They are by some regarded as the homologues of the interclavicle or episternal bone of monotremes.

THE RIBS.

The **ribs** (costæ) of which there are twelve pairs, form a series of curved osseous bands which support the thoracic wall; posteriorly they articulate with the dorsal or thoracic vertebræ, anteriorly each rib is provided with a costal cartilage. The first seven ribs articulate with the sternum by means of their cartilages, and are termed the **true** (costæ veræ) or **vertebro-sternal ribs**. The lower five ribs are not so supported, and are described as the **false ribs** (costæ spuriæ). Of these the eighth, ninth, and tenth are united by their cartilages to the cartilage of the seventh rib, and are called the **vertebro-chondral ribs**, whilst the last two ribs are free at their anterior extremities, and are named the **floating** or **vertebral ribs**.

A **typical rib** consists of a **head** (capitulum costæ), a **neck** (collum costæ), a **tubercle** (tuberculum costæ), and a **shaft** (corpus costæ), on which, near its posterior end, is the **angle** (angulus costæ).

The **head**, placed on the posterior or vertebral end of the bone, is somewhat expanded. Internally its articular surface is wedge-shaped and divided into two parts, an upper and lower, by a ridge or crest (crista capituli), to which the inter-articular ligament is attached. Of these two facets the lower is usually the larger, and articulates with the upper facet on the body of the vertebra in numerical correspondence with it, whilst the upper facet is for the corresponding area on the lower part of the body of the vertebra above. The head is supported by a more or less constricted bar of bone, the **neck**. This becomes continuous with the shaft externally, at which point there is a well-marked tubercle on its posterior surface. The anterior surface of the neck is smooth; its posterior aspect is rough, and pierced by numerous small holes for vessels. Here is attached the middle costo-transverse ligament. Not uncommonly the upper border of the neck is lipped and ridged (crista colli costæ), and affords attachment to the anterior costo-transverse ligament.

The **tubercle** consists of an articular and a non-articular part; the former is internal to and below the latter. Its articular surface, of rounded or oval shape, is directed downwards, backwards, and a little inwards, and rests upon a facet on the transverse process of the vertebra in numerical correspondence with the rib. The non-articular part, most prominent in the upper ribs, has the fibres of the posterior costo-transverse ligament attached to it. It is usually separated from the upper border of the neck and shaft by a groove, in which lies the external branch of the posterior division of the thoracic nerve.

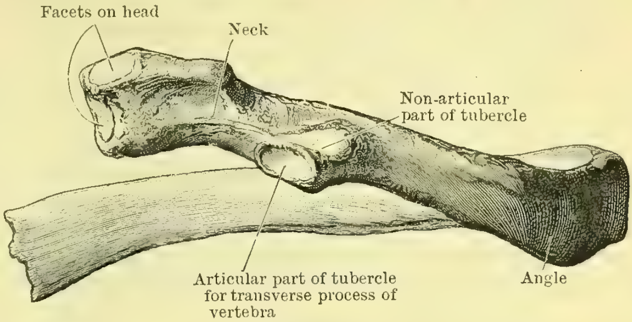


FIG. 73.—FIFTH RIGHT RIB AS SEEN FROM BEHIND.

The **shaft** (corpus costæ) is thin, flattened, and band-like. Its length varies much; the seventh and eighth, which are usually the longest, are from two and a half to three times the length of the first and twelfth ribs respectively. The shafts are curved so as to adapt them to the form of the thoracic wall. More acute in the upper members of the series, where the shafts are shorter, the curve opens out in the middle and lower parts of the thorax, where the diameters of that cavity are greater. The curve, however, is not uniform. Including the whole length of the bone, it will be seen to be most accentuated towards the hinder part, where, in correspondence with the point at which the bend is most pronounced, there is a rough ridge placed obliquely across the outer surface of the shaft; this is the **angle** (angulus costæ). The distance between the angle and the tubercle is greatest on the eighth rib; above that, the width between these two points gradually decreases until, in the case of the first rib, the two coincide. Below the level of the eighth rib the distance slightly diminishes in conformity with the general narrowing of the thorax below that level.

Combined with this curve, there is in many of the ribs a twist. This may best be understood if the student will take a strip of stiff paper and bend it in the form of the curve of the rib. If, after he has done this, he pulls down the fore end and turns up the hind end of the strip, he will have imparted to the strip of paper a twist similar to that met with in the rib. This appearance is best seen in the middle members of the series, notably in the seventh and eighth ribs, above and below which it gradually becomes less marked. It is the occurrence of this twist which prevents the extremities of the ribs, together with the shaft, from resting on the same plane surface. To this rule there are certain notable exceptions, viz. the first and second, the twelfth, and not infrequently the eleventh.

The shaft has two surfaces, an internal and an external, and two borders, a superior and an inferior. The external surface, which is smooth, conforms to the general vertical convexity of the thorax, being directed upwards in the first rib, upwards and outwards in the higher ribs, outwards in the middle series, and outwards and slightly downwards in the tenth, eleventh, and twelfth. The internal surfaces are arranged conversely and are covered by the parietal pleura. Towards the sternal end of the middle ribs, where the downward twist is most marked, there is often an oblique line across the outer surface. This is sometimes referred to as the anterior angle. The upper border of the shaft is thick and rounded behind, thinner and sharper in front; to it are attached the fibres of the internal and external intercostal muscles. The lower border is grooved behind at the expense of the inner surface, and is overhung externally by a sharp margin. Anteriorly this **subcostal groove** (sulcus costalis) fades away, and its lips coalesce to form a rounded edge. The intercostal vessels and nerve are lodged in this groove, whilst its lips afford attachment to the external and internal intercostal muscles respectively. On the floor of the groove may also be seen the openings of the canals for the transmission of the nutrient vessels, which are directed towards the vertebral end of the rib.

The anterior or sternal extremity of the shaft, often slightly enlarged, displays an elongated oval pit into which the costal cartilage is sunk.

Peculiar Ribs.—The first, second, tenth, eleventh, and twelfth ribs all display characters by which they can be readily recognised.

The **first rib** can be easily distinguished from the others by its size, curvature, and flattened form. The **head**, which is of small size, has a single oval or circular facet, which is directed inwards and slightly backwards for articulation with the side of the body of the first dorsal vertebra. The **neck** is flattened from above downwards, and is slightly down-turned towards the end which supports the head. Its anterior border is rounded and smooth; its posterior edge rough for the attachment of ligaments. At the point where the neck joins the shaft posteriorly, a prominent **tubercle** curves upwards and backwards. The inner and under surface of this process has a small circular facet which rests on a corresponding articular surface on the transverse process of the first dorsal vertebra. The **angle** coincides with the tubercle, and thus assists in emphasising its prominence. The surfaces of the body of the rib are directed upwards and downwards, its borders inwards and outwards. If the finger be run along the thin inner border, a distinct spine or tubercle can be readily felt about an inch or an inch and a quarter from its anterior extremity. This is the **scalene tubercle** (tuberculum scaleni) for the attachment of the scalenus anticus muscle. There is a shallow, oblique groove crossing the upper surface of the shaft in front of this for the lodgment of the subclavian vein; whilst behind the tubercle there is another groove, usually better marked, and passing obliquely forwards for the subclavian artery (sulcus subclaviæ). The space on the upper surface of the rib between this latter groove and the tubercle posteriorly is somewhat rough, and affords attachment to the fibres of the scalenus medius muscle. The anterior extremity of the rib is thickened and often expanded for the reception of its costal cartilage, which is not infrequently ossified. The under surface of the rib is smooth and is covered by pleura. The outer convex border, thin in front, is usually thick and rough behind the subclavian groove, where it has attached to it the fibres of the first digitation of the serratus magnus. Along this edge, also, are attached the external and internal intercostal muscles of the first intercostal space. The inner concave border is thin, and has connected with it the aponeurotic expansion known as Sibson's fascia.

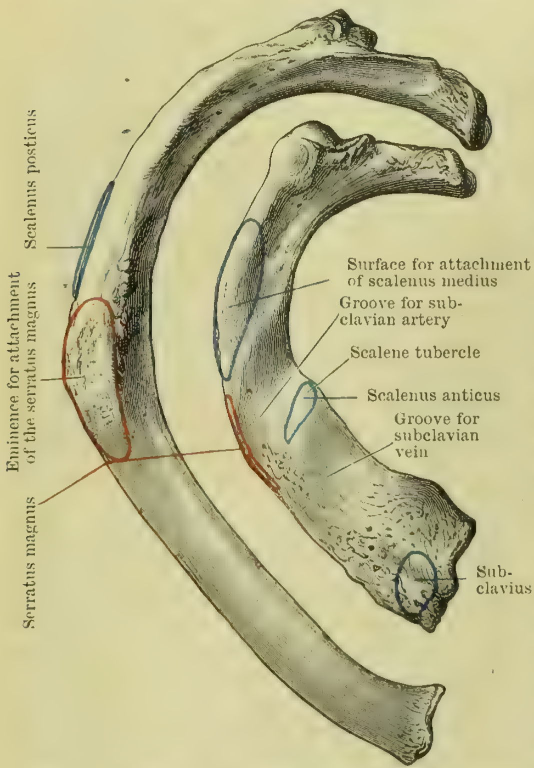


FIG. 74.—FIRST AND SECOND RIGHT RIBS AS SEEN FROM ABOVE.

The **second rib** may be distinguished by the size of its curve; the absence of any twist on its shaft, so that it can be laid flat on the table; the oblique direction of the surfaces of its shaft, the outer being directed upwards and outwards, whilst the inner is turned downwards and inwards; and the presence of a well-marked, rough, oval area about the middle of its outer surface and lower border for part of the first, and the whole of the second digitation of the serratus magnus muscle. The head has two facets, and the angle is close to the tubercle posteriorly.

The **tenth rib** has usually only a single articular facet on the head.

The **eleventh** and **twelfth ribs** are recognised by their length. Their heads,

usually large in proportion to their shafts, support a single facet for articulation with the eleventh and twelfth dorsal vertebræ respectively. The tubercles are ill-developed, and have no articular facets. The angle is faintly marked on the eleventh, scarcely perceptible on the twelfth. Their anterior extremities are narrow and pointed, and tipped with cartilage. The subcostal groove is absent in the twelfth, and but slightly seen in the eleventh. The twelfth is considerably shorter than the eleventh rib.

Architecture.—Each rib consists of a curved and flattened bar of bone, the interior of which is loose and cancellous, whilst the investing envelope is compact. The inner table is much the stronger, attaining its maximum thickness opposite the angle—in front and behind which it becomes gradually reduced. The outer table, much thinner, is stoutest opposite the angle; on the posterior surface of the tubercle and neck it forms but a thin layer. The compact layers forming the upper and lower borders are not so thick as those forming the inner and outer surfaces. The cancellous tissue, loose and open in the shaft, is most compact in the region of the head and towards the anterior extremity.

Variations.—The **number of ribs** may be increased or diminished. Increase may occur by the addition of a cervical rib due to the independent development of the costal element in the transverse process of the seventh cervical vertebra. This may happen on one or both sides. The range of development of these cervical ribs varies; they may unite anteriorly with the sternum, or they may be fused anteriorly with the cartilage of the first rib, or the cervical rib may be free. It may in some instances be represented mainly by a ligamentous band, or its vertebral and sternal ends may be alone developed, the intermediate part being fibrous. At times the vertebral end only may be formed and may be fused with the first rib, thus leading to the formation of a bicipital rib such as occurs in many cetaceans. Increase in the number of ribs may also be due to the ossification of the costal element which is normally present in the embryo in connexion with the first lumbar vertebra (Rosenberg, *Morph. Jahrb.* i.). Reduction in the number of ribs is less common. The twelfth rib rarely aborts; in some cases the first rib is rudimentary. Cases of congenital absence of some of the ribs have been recorded by Hutchinson, Murray, and Ludeke.

Fusion of adjacent ribs may occur. (Lane, *Guy's Hosp. Reports*, 1883.)

Variations in form may be in great part due to the occupation of the individual and the constricting influence of corsets. Independently of these influences, the fore part of the shaft is sometimes cleft so as to appear double; at other times the cleft may be incomplete so as to form a perforation. Occasionally adjacent ribs are united towards their posterior part by processes having an intermediate ossicle between (Meckel), thus recalling the condition normally met with in birds; more usually, however, the bony projections are not in contact.

The number of true or vertebro-sternal ribs may be reduced to six, or increased to eight (see *ante*, p. 93).

Ossification.—Ossification begins in the cartilaginous ribs about the sixth week, and rapidly extends along the shaft, so that by the end of the third month it has reached the permanent costal cartilage. The sixth and seventh ribs are the earliest to ossify. The first rib being the last (Lambertz). At puberty, or before, secondary centres appear; of these there are three—an epiphysis for the articular surface of the tubercle, one for the non-articular part of the same process, and one for the head. By the twenty-fifth year fusion between these and the shaft is complete.

THE COSTAL CARTILAGES.

The **costal cartilages,** of which there are twelve pairs, are bars of hyaline cartilage united to the anterior extremities of the ribs, into which they are recessed and held in position by the periosteum. Through these cartilages the first seven ribs are connected directly with the sternum by means of synovial joints corresponding to the notches along the margins of the breast bone. To this there is an exception in the case of the first rib, the cartilage of which is directly blended with the manubrium sterni. The eighth, ninth, and tenth are connected indirectly with the sternum by their union with each other, and their articulation, through the medium of the eighth with the seventh rib cartilage; whilst the eleventh and twelfth cartilages tip the ribs to which they belong, and lie free in the muscles of the flank. The costal cartilages increase in length from the first to the seventh, below which they become shorter. The first inclines obliquely downwards and inwards to unite with the upper angles of the manubrium. The second lies more or less horizontally. The third to the seventh gradually become more and more curved, inclining downward from the extremities of their respective ribs, and then turning upwards to reach the sternum. The tenth cartilage articulates by means

7

of a synovial joint with the ninth, the ninth with the eighth, and the eighth with the seventh. There are also surfaces for the articulation of the seventh with the sixth, and sometimes for the sixth with the fifth.

Variations.—Occasionally a costal cartilage is unduly broad, and may be pierced by a foramen. The number of costal cartilages connected with the sternum may be reduced to six or increased to eight (see p. 93). In advanced life there is a tendency towards ossification in the layers underlying the perichondrium, more particularly in the case of the first rib cartilage, in which it may be regarded as a more or less normal occurrence.

THE THORAX AS A WHOLE.

The bony and cartilaginous thorax is barrel-shaped, being narrower above than below, and compressed from before backwards. Its posterior wall is longer than its anterior, and its transverse width, which reaches its maximum opposite the eighth or ninth rib, is much in excess of its sagittal diameter. This is largely owing to the forward projection of the thoracic part of the vertebral column into the thoracic cavity.

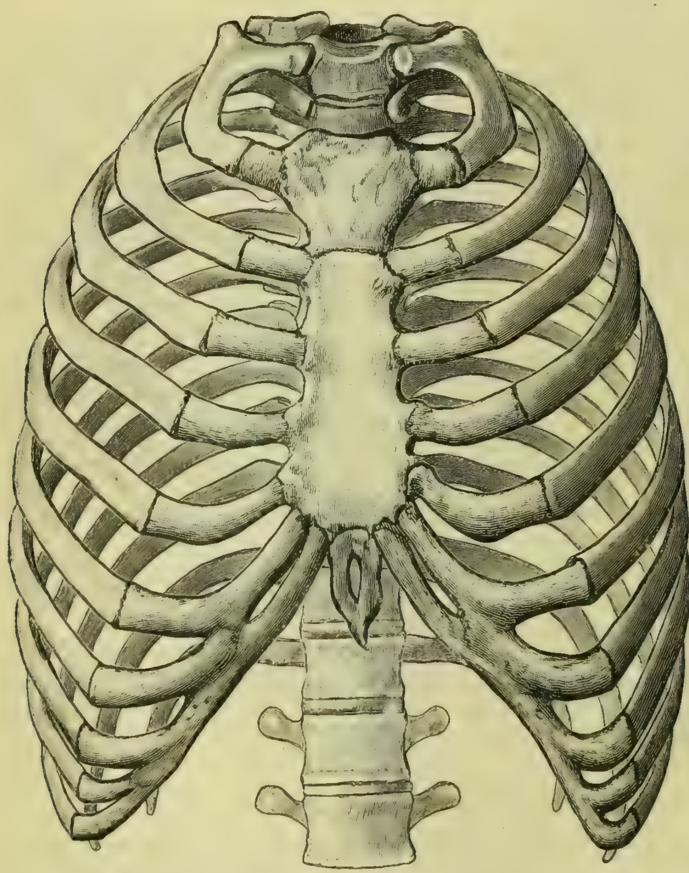


Fig. 75.—The Thorax as seen from the Front.

The **anterior wall** is formed by the ribs and rib cartilages, together with the sternum. The **posterior wall** comprises the thoracic part of the vertebral column and the ribs as far as their angles. Owing to the backward curve of the ribs, and the projection forwards of the vertebral bodies, the antero - posterior diameter of the thoracic cavity is considerably greater on either side of the middle line than in the mesial plane, thus allowing for the lodgment of the rounded posterior borders of the lungs. For the same reason the furrow on either side of the spinous processes of the thoracic vertebræ is converted into a broad groove (vertebral groove), the floor of which is in part formed by the ribs as far as their angles. The grooves so formed are each occupied by the fleshy mass of the erector spinæ muscle.

The **lateral walls** are formed by the costal arches. The ribs which run obliquely from above downwards and forwards do not lie parallel to each other, but spread somewhat, so that the intervals between them (intercostal spaces) are wider in front than behind.

The **superior aperture** or inlet formed by the body of the first thoracic vertebra behind, the arches of the first rib on either side, and the upper border of the manubrium sterni in front, is contracted and of reniform shape. The plane of the inlet is oblique from behind downwards and forwards, so that in expiration the

upper border of the sternum lies on a level with the disc between the second and third thoracic vertebræ.

The **lower aperture,** of large size, is bounded in the middle line behind by the twelfth thoracic vertebra; passing thence the twelfth ribs slope outwards, downwards, and forwards. From these a line carried horizontally forwards from their tips touches the end of the eleventh rib, and then curving slightly upward reaches the cartilage of the tenth rib. Here it follows the confluent margins of the cartilages of the tenth, ninth, eighth, and seventh ribs, finally reaching the xiphoid cartilage, where it forms with the costal margin of the opposite side the subcostal angle, the summit of which coincides with the xiphi-sternal articulation; in expiration this joint usually lies on a level with the intervertebral disc between the ninth and tenth thoracic vertebræ, and corresponds with the surface depression familiarly known as the pit of the stomach. The inferior aperture of the thorax is occupied by the vault of the diaphragm.

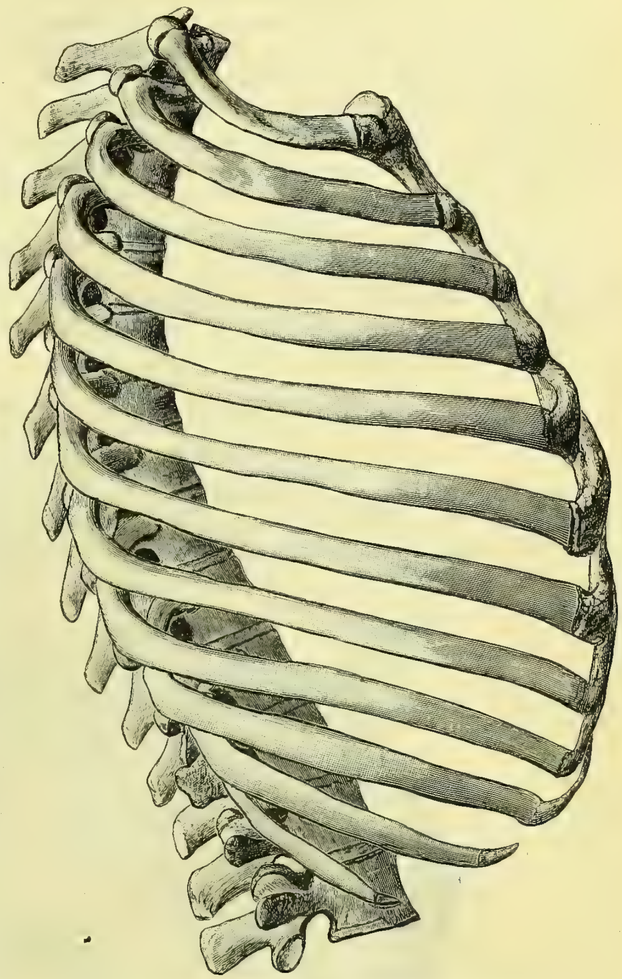


Fig. 76.—The Thorax as seen from the Right Side.

In the fœtal condition the form of the thorax differs from that of the adult. It is laterally compressed—in this respect resembling the simian type. Its antero-posterior diameter is relatively greater than in the adult. At birth changes in form take place dependent on the expansion of the lungs; during subsequent growth, the further expansion of the thoracic cavity in a transverse direction is correlated with the assumption of the erect posture, and the use of the fore-limbs as prehensile organs.

Sexual Differences.—The thorax of the female is usually described as being proportionately shorter and rounder than the male. It also tends to narrowness in the lower segment. It is hardly necessary to point out that the natural form is often modified by the use of tight or ill-fitting corsets.

THE BONES OF THE SKULL (Ossa Cranii).

The term skull (cranium) is commonly employed to signify the entire skeleton of the head. This comprises the bony envelope which surrounds the brain (cranium cerebrale), and the osseous structures which support the face (cranium viscerale, ossa faciei).

In catalogues of craniological collections the terms used are as follows:—

Skull = entire skeleton of head, including the mandible.
Cranium = the skull, minus the mandible.
Calvaria = that part of the skull which remains after the bones of the face have been removed or destroyed.

The cranium cerebrale is composed of the **occipital** (os occipitale), the **sphenoid** (os sphenoidale), the **ethmoid** (os ethmoidale), and the **frontal** (os frontale), the two **parietals** (ossa parietalia), and the two **temporals** (ossa temporalia)—eight bones in all.

The bones of the face (cranium viscerale, ossa faciei) include the following:— Two single, viz. the **vomer** (vomer), and the **inferior maxilla** or **mandible** (mandibula), and twelve bones, arranged in pairs, viz. the **superior maxillary** (maxillæ), **malar** (ossa zygomatica), **palate** (ossa palatina), together with the **lachrymal** (ossa lacrymalia), **nasal** (ossa nasalia), and **inferior turbinated** (conchæ inferiores)—fourteen bones in all.

According to the scheme of international nomenclature, the inferior turbinals, the lachrymals, the nasals, and the vomer are included under the cranium cerebrale, and not with the cranium viscerale.

The hyoid bone is usually described along with the skull. If, in addition, the bones of the middle ear, three on each side (malleus, incus, and stapes), be included, the skeleton of the head consists of twenty-nine bones.

The separate bones will first be described, and then the skull will be considered as a whole and in section.

THE SEPARATE BONES OF THE SKULL.

The Frontal Bone.

The **frontal bone** (os frontale), situated in the fore part of the cranium, is a single bone formed by the fusion in early life of two symmetrical halves. It consists of a **frontal part**, which corresponds to the region of the forehead; an **orbital**

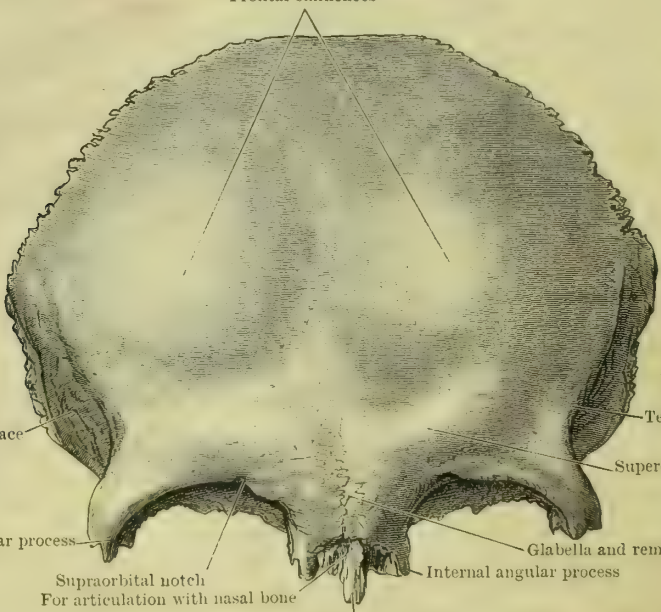


Fig. 77.—Frontal Bone (Anterior View).

part, which enters in the structure of the roof of the orbits; and a **nasal part**, which assists in forming the roof of the nasal fossæ.

The **frontal part** (pars frontalis) is the shell-like portion of the bone which rises upwards above the orbital arches. Its external surface is rounded from side to side and from above downwards. This convexity is most pronounced about $1\frac{1}{4}$ inches above the orbital margins on either side of the middle line, constituting what are known as the **frontal eminences** (tubera frontalia). These mark the original sites of the centres from which the bone ossifies. The lower margin of this part is formed on either side of the middle line by the curved **orbital margins** (margines supraorbitales), the outer and inner extremities of which

constitute the **external** and **internal angular processes** respectively. The latter descend to a lower level than the former, and articulate with the lachrymal bones, being separated from each other by a rough articular surface—the **nasal notch** for the nasal and superior maxillary bones. The curve of the orbital margin varies in different individuals and races; towards its inner third it is crossed by a groove, not unfrequently converted into a foramen—the **supraorbital notch** or **foramen** (incisura sive foramen supraorbitalis). Through this there pass the supraorbital nerve and artery. Above the supraorbital margin the character of the bone displays marked differences in the two sexes: in the male, above the interval between the two internal angular processes, there is usually a well-marked prominence, called the **glabella**, from this the fulness extends outwards above the orbital margin, varying in degree and extent, and forming the elevations known as the **supraorbital** or **superciliary ridges** (arcus superciliares). The prominence of these naturally reacts on the character of the supraorbital margins, which are thicker and more rounded in the male than in the female. Passing upwards over the glabella, the remains of the suture which originally separated the two halves of the frontal bone can usually be seen; above this point all trace of the suture is generally obliterated.

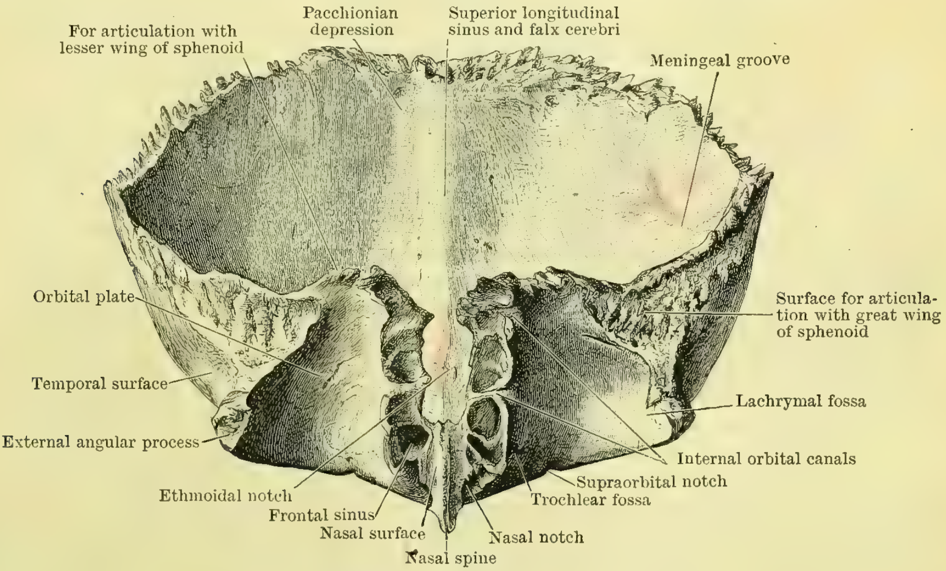


FIG. 78.—FRONTAL BONE AS SEEN FROM BELOW.

Extending upwards from the external angular process is a well-marked ridge, which curves upwards and slightly inwards, then turning backwards it arches across the lateral aspect of the bone. This is the **temporal ridge** or **crest** (linea temporalis), which serves to separate the anterior surface of the frontal portion of the bone from its temporal aspect. The latter (facies temporalis) forms the floor of the upper and anterior part of the temporal fossa, and serves for the attachment of the temporal muscle.

The **orbital part** of the bone (pars orbitalis) consists of two transversely-curved plates, each having the form of a sextant; their inner edges, which are cellular, lie parallel to each other, and are separated in their posterior half by the **ethmoidal notch** (incisura ethmoidalis), in which the ethmoid bone is lodged. The edges of the notch on either side are grooved in front and behind by the **anterior** and **posterior ethmoidal foramina**, which are completed when the ethmoid is *in situ*. The anterior transmits the internal branch of the nasal nerve and the anterior ethmoidal vessels; the posterior, the posterior ethmoidal vessels. In front of the ethmoidal notch is the nasal notch, from the centre of which the **nasal process** projects downwards and forwards to terminate in the **nasal spine** (spina nasalis), which lies between, and articulates with the nasal bones and perpendicular plate of the ethmoid. On either side of the root of this process the bone is grooved obliquely from above downwards and

forwards, and enters into the formation of the narrow roof (pars nasalis) of the nasal fossæ. Anteriorly the nasal notch is limited by a rough U-shaped articular surface, the median part of which articulates with the nasal bones, whilst on either side the nasal processes of the superior maxillæ are united with it. Behind this, amid the broken cells, the passages leading into the frontal sinuses are readily distinguished, and here the inner edges of the orbital plates articulate with the lachrymal bones.

The **orbital plate** is thin and brittle. In front it is bounded by the superior orbital margin, just within which, midway between the internal angular process and the supraorbital notch there is a small shallow depression (fovea trochlearis), often displaying a spicule of bone arising from its edge (spina trochlearis), which affords attachment to the pulley of the superior oblique muscle of the eyeball. Externally the orbital plate is overhung by the orbital margin and the external angular process, and in the hollow so produced (fossa glandulæ lachrymalis) the lachrymal gland is lodged. The extremity of the **external angular process** (processus zygomaticus) articulates with the frontal process of the malar bone. Behind this the irregular edge of the orbital plate is united with the great wing of the sphenoid by a triangular area, which also extends on to the inferior aspect of the temporal surface of the frontal bone. The apex of the orbital plate, for the space of about half an inch, articulates with the lesser wing of the sphenoid.

The *cerebral surface* of the bone forms a fossa in which lie the fore and under parts of the frontal lobes of the cerebrum, the convolutions of which impress their form on the inner aspect of the bone. Here, too, on either side of the middle line, may be seen depressions for the lodgment of Pacchionian bodies. Descending from the centre of the upper margin of the bone is a vertical groove, the **frontal sulcus**; narrowing below, this ends in a ridge—the **frontal crest**—which nearly reaches the fore part of the ethmoidal notch, where it terminates in a small orifice, the foramen cæcum, placed usually in the suture between the fore part of the ethmoid and the frontal. This foramen may, or may not, transmit a small vein from the nose to the commencement of the superior longitudinal sinus. This sinus, which is interposed between the layers of the falx cerebri, is at first attached to the frontal crest, but subsequently occupies the frontal sulcus. Deeply concave from side to side and from above downwards, the lateral aspects of the fossa are seen to be traversed by small grooves for the anterior branches of the middle meningeal arteries. Below, the orbital plates bulge into the floor of the fossa, so that the ethmoidal notch appears recessed between them. On either side of the notch faint grooves for the meningeal branches of the ethmoidal vessels may be seen. The circumference of the fossa is formed by the serrated edges of the bone which articulate with the parietals above, and on either side below with the great and lesser wings of the sphenoid.

Connexions.—The frontal articulates with twelve bones, viz. posteriorly with the parietals and sphenoid; externally with the malars; inferiorly and internally with the nasals, superior maxillæ, lachrymals, and ethmoid.

Architecture.—The frontal bone is composed, like the other bones of the cranial vault, of two layers of compact tissue, enclosing between them a layer of spongy cancellous texture—the diploë. In certain definite situations, owing to the absorption of the intermediate layer, the bone is hollow, forming the **frontal air sinuses.** The position and extent of these is to some extent indicated by the degree of projection of the superciliary ridges, though this must not be taken as an absolutely reliable guide, for cases are recorded where the ridges were low and the sinuses large, and *vice versa*. Of much surgical importance, these air-spaces only attain their full development after the age of puberty, being of larger size in the male than in the female, a circumstance which accounts for the more vertical appearance of the forehead in woman as contrasted with man. Usually two in number, they are placed one on either side of the middle line, and communicate by means of the infundibulum with the nasal fossa of the same side. It is exceptional to find the sinuses of opposite sides in communication with each other, as they are generally separated by a complete partition which, however, is occasionally much deflected to one or other side. Logan Turner ("On the Illumination of the Air Sinuses of the Skull, with some Observations upon the Surgical Anatomy of the Frontal Sinus," *Edin. Med. Journ.* May 1898) gives the average dimensions of these sinuses as follows:—Height, 31 mm., *i.e.* from the fronto-nasal aperture upwards; breadth, 30 mm., *i.e.* from the septum horizontally outwards; depth, 17 mm., from the anterior wall at the level of fronto-nasal suture backwards along the orbital roof. Exceptionally large sinuses are sometimes met with extending backwards over the orbit so as to form a double roof to that space. There is a specimen in the Oxford collection in which the

sinus is so large, and extends so far back, that the optic nerve is carried through it in a bony tube. Another point of some practical importance is that the sinuses are hardly ever symmetrical. It is rare to meet with cases of their complete absence, although sometimes the sinus on one or other side may be wanting.

The external angular process, from the arrangement of its surfaces and the density of its structure, is particularly well adapted to resist the pressure to which it is subjected when the jaws are firmly closed.

Variations.—That most frequently met with is a persistence of the suture which unites the two halves of the bone in the infantile condition: skulls displaying this peculiarity are termed **metopic.** The researches of various observers—Broca, Ranke, Gruber, Manouvrier, Anoutchine, and Papillault (*Rev. mens. de l'école d'Anthropol. de Paris*, année 6, n. 3)—point to the more frequent occurrence of this metopic suture in the higher than in the lower races of man; and Calmette asserts its greater frequence in the brachycephalic than the dolichocephalic type. Separate ossicles (Wormian bones) may occur in the region of the anterior fontanelle. The fusion of these with one or other half of the frontal explains how the metopic suture is not always in line with the sagittal suture (Stieda, *Anat. Anz.* 1897, p. 227); they occasionally persist, however, and form by their coalescence a bregmatic bone (G. Zoja, *Bull. Scientifico*, xvii. p. 76, Pavia). Turner (*Challenger Reports*, part xxix.) records an instance of direct articulation of the frontal with the orbital plate of the superior maxilla in a Bush skull, and other examples of the same anomaly, which obtains normally in the skulls of the chimpanzee and gorilla, have been observed (*Journ. Anat. and Physiol.* vol. xxiv. p. 349).

Ossification.—Ossification begins in membrane from two centres, which appear about the sixth or seventh week, one on either side immediately above the orbital margin. By extension inwards and backwards from these the orbital plates are formed. Serres, Rambaud, and Renault and v. Ihering describe the occurrence of three pairs of secondary centres somewhat later: one pair for the nasal spine on either side of the foramen cæcum; a centre on either side in correspondence with the position of each trochlear fossa; and a centre for each external angular process. Fusion between these secondary and the primary centres is usually complete about the sixth or seventh month of fœtal life. At birth the two symmetrical halves of the bone are separated by the metopic suture, obliteration of which gradually takes place, so that about the fifth or sixth year it is more or less completely closed, traces only of the suture being left above and below. In about eight per cent of Europeans, however, the suture persists in the adult (see *ante*). At birth the supraorbital notches lie near the middle of the supraorbital arches.

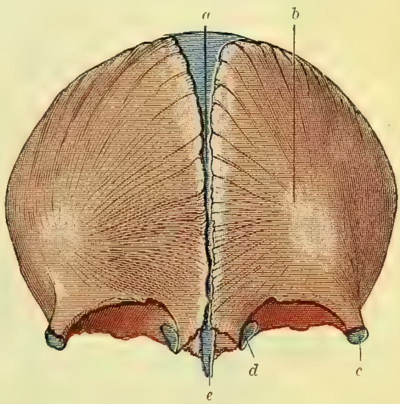


FIG. 79.—OSSIFICATION OF FRONTAL BONE.

a, Metopic suture still open. *b*, Position of primary centre. *c*, Centre for external angular process. *d*, Centre for region of trochlea. *e*, Centres for nasal spine.

Traces of the frontal sinuses may be met with about the second year, but it is only about the age of seven that they can be definitely recognised. From that time they increase in size till the age of puberty, subsequent to which time they attain their maximum development.

THE PARIETAL BONES.

The **parietal bones** (ossa parietalia), two in number, are placed on either side of the vault of the cranium, articulating with the frontal anteriorly, the occipital posteriorly, and the temporals and sphenoid inferiorly. Each bone possesses an external and internal surface, four borders, and four angles.

The *external surface,* convex from above downwards and from before backwards, displays towards its centre a more or less pronounced elevation, the **parietal eminence** (tuber parietale). This marks the position of the primitive ossific centre, and not unfrequently corresponds to the point of maximum width of the head. At a variable distance from the lower border of the bone, and more or less parallel to it, two curved lines can usually be distinguished; these together constitute the **temporal crest.** The **superior temporal line** (linea temporalis superior) serves for the attachment of the temporal fascia; the **inferior temporal line** (linea temporalis inferior) defines the attachment of the temporal muscle, the extent and development of which necessarily determines the position of the crest. The surface below the crest enters into the formation of the floor of the **temporal fossa,** and is called the **planum temporale**; it

also affords origin to the temporal muscle, and is often faintly marked by grooves which indicate the course of the middle temporal artery.

Above the superior temporal line the bone is covered only by the tissues of the scalp. Near its upper border, and about an inch from its posterior superior angle, is the small **parietal foramen** (foramen parietale), through which pass a small arteriole and an emissary vein.

The *inner* or *cerebral aspect* is concave from side to side and from above downwards, moulded over the surface of portions of the frontal, parietal, occipital, and temporal lobes of the cerebrum, it displays impressions corresponding to the arrangement of the convolutions of these portions of the brain. It also presents a series of well-marked grooves for the lodgment of the branches of the middle meningeal artery; these radiate from the anterior inferior angle of the bone, the best marked running upwards at some little distance behind and parallel to its anterior border. Within the upper margin are a series of depressions for Pacchionian bodies, and here also the bone is channelled so as to form a groove (sulcus sagittalis),

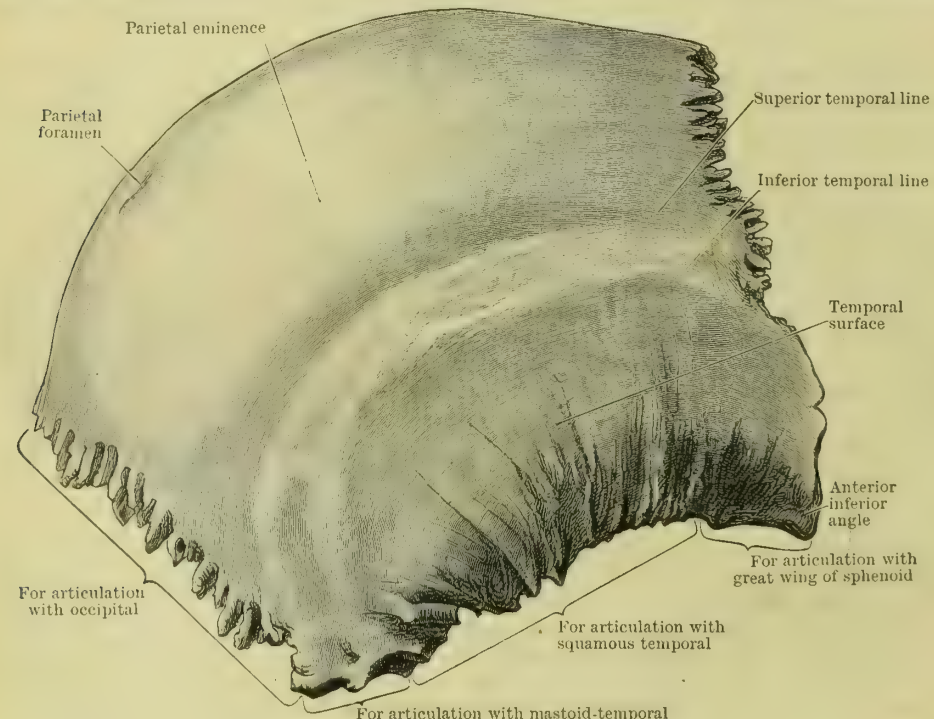


FIG. 80.—RIGHT PARIETAL BONE (Outer Side).

which is completed by articulation with its fellow of the opposite side. Within this groove lies the superior longitudinal venous sinus, and to its edges the falx cerebri is attached. Close to the inferior posterior angle there is also a curved groove, the lateral sulcus, in which the lateral venous sinus is lodged.

The *anterior*, *superior*, and *posterior borders* are deeply serrated. The anterior articulates with the frontal bone, and constitutes the coronal suture; the posterior is united with the occipital bone, and forms the lambdoid suture. The superior border articulates with its fellow of the opposite side by means of the sagittal suture; in the interval between the two parietal foramina this suture is usually simple in its outline. The *anterior superior angle* (angulus frontalis) is almost rectangular, and corresponds to the site of the anterior fontanelle. The *posterior superior angle* (angulus occipitalis), usually more or less rounded, corresponds in position to the posterior fontanelle. The *inferior border* is curved, and shorter than the others, it lies between the anterior and posterior inferior angles. Sharp and bevelled at the expense of its outer table, it displays a fluted arrangement, and articulates with the squamous part of the temporal bone. The *anterior inferior angle* (angulus

sphenoidalis), pointed and prominent, articulates with the great wing of the sphenoid. It is wedged into the angle formed by the union of that bone with the frontal, and is bevelled at the expense of its inner table anteriorly, whilst inferiorly it is thinned at the expense of its outer table. The *posterior inferior angle* (angulus mastoideus) is a truncated angle lying between the inferior and posterior borders. It is deeply serrated, and articulates with the mastoid process of the temporal bone. Not unfrequently there is a channel in this suture which transmits an emissary vein.

Connexions.—The parietal bone articulates with its fellow, with the frontal, occipital, mastoid and squamous temporal, and with the sphenoid.

Architecture.—Thin towards its lower part, where it enters into the formation of the temporal fossa, it is thickest along the superior border and in the neighbourhood of the posterior superior angle.

Variations.—A number of cases have been recorded in which the parietal is divided into an upper and lower part by an antero-posterior suture parallel to the sagittal suture. Coraini (*Atti. d. XI. Congr. Med. Internaz. Roma*, 1894, vol. v.) records a case in which the parietal was incompletely divided into an anterior and posterior part by a vertical suture. The parietal

FIG. 81.—RIGHT PARIETAL BONE (Inner Surface).

foramina vary greatly in size, and to some extent in position. They are sometimes absent on one or other side, or both. They correspond in position to the sagittal fontanelle. Sometimes the ossification of this fontanelle is incomplete and a small transverse fissure remains. The parietal foramen represents the patent external extremity of this fissure after its edges have coalesced.

Ossification.—Ossification takes place in membrane by the deposition of earthy matter, the centre for which, most probably formed by the coalescence of two nuclei, appears over the parietal eminence about the sixth or seventh week of fœtal life; from this, it spreads in a radial manner towards the edges of the bone, where, however, the membranous condition still for some time persists constituting the fontanelles. These correspond in position to the angles of the bone. Ossification is also somewhat delayed in the region of the parietal foramina, constituting what is known as the sagittal fontanelle, a membranous interval which is not unfrequently apparent, even at birth.

THE OCCIPITAL BONE.

The **occipital bone** (os occipitale), placed at the back and lower part of the cranium, consists of three parts, arranged around a large oval hole, called the

occipital foramen or foramen magnum. The expanded curved plate behind the foramen is the **tabular** or **squamous part.** The thick rod-like portion in front of the foramen is the **basilar process.** On either side the foramen is bounded by the **lateral** or **condylic portions.**

The **tabular or squamous part** (squama occipitalis) in shape somewhat resembles a Gothic arch, and is curved from side to side and from above downwards. It forms inferiorly a small portion of the middle of the posterior boundary of the foramen magnum, and unites on either side of that with the lateral parts of the bone. About the centre of the *external surface* of the squama there is a prominence—the **external occipital protuberance** (protuberantia occipitalis externa), which varies considerably in its distinctness and projection, and serves for the attachment of the ligamentum nuchæ. From the protuberance on either side two lines curve out towards the external angles of the bone. These are known respectively as the **highest** and

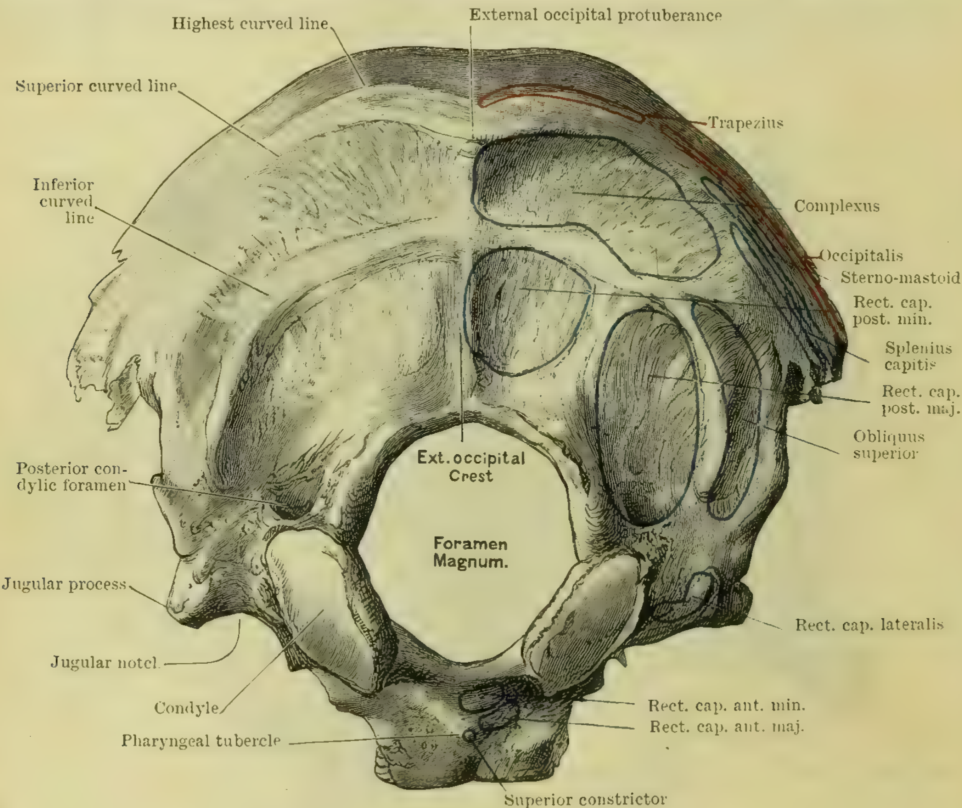


Fig. 82.—Occipital Bone as seen from Below.

superior curved lines (linea nuchæ suprema and linea nuchæ superior). To the upper of these the epicranial aponeurosis is attached, whilst the lower serves for the origin of the trapezius and occipitalis muscles and the insertion of the sterno-mastoid and splenius capitis muscles. The two lines together serve to divide the external surface of the tabular part into an upper or **occipital portion** (planum occipitale), covered by the hairy scalp and a lower or **nuchal part** (planum nuchale) serving for the attachment of the fleshy muscles of the back of the neck. As a rule the occipital part bulges backwards beyond the external occipital protuberance; exceptionally, however, the latter process is the most outstanding part of the bone.

The **nuchal plane**, irregular and rough, is divided into two lateral halves by a median ridge—the **external occipital crest** (linea nuchæ mediana), which stretches from the external occipital protuberance above to the posterior border of the foramen magnum below. Crossing the nuchal plane transversely, about its middle, is the **inferior curved line** (linea nuchæ inferior), which passes outwards and forwards on either side towards the lateral margins of the bone. The areas thus marked out

serve for the attachment of the complexus, obliquus superior, and rectus capitis posticus major and minor muscles.

The *internal surface* of the squama, concave from side to side and from above downwards, is subdivided into four fossæ by a crucial arrangement of ridges and grooves. The upper pair of fossæ lodge the occipital lobes of the cerebrum, the lower pair the lobes of the cerebellum. Near the centre of this aspect of the bone is the **internal occipital protuberance** (protuberantia occipitalis interna), an irregular elevation, the sides of which are variously channelled according to the disposition of the grooves. Leading from this to the hinder margin of the foramen magnum is a sharp and well-defined ridge, the **internal occipital crest** (crista occipitalis interna), which serves for the attachment of the falx cerebelli, a process of dura mater which separates the two cerebellar hemispheres. Passing upwards from the

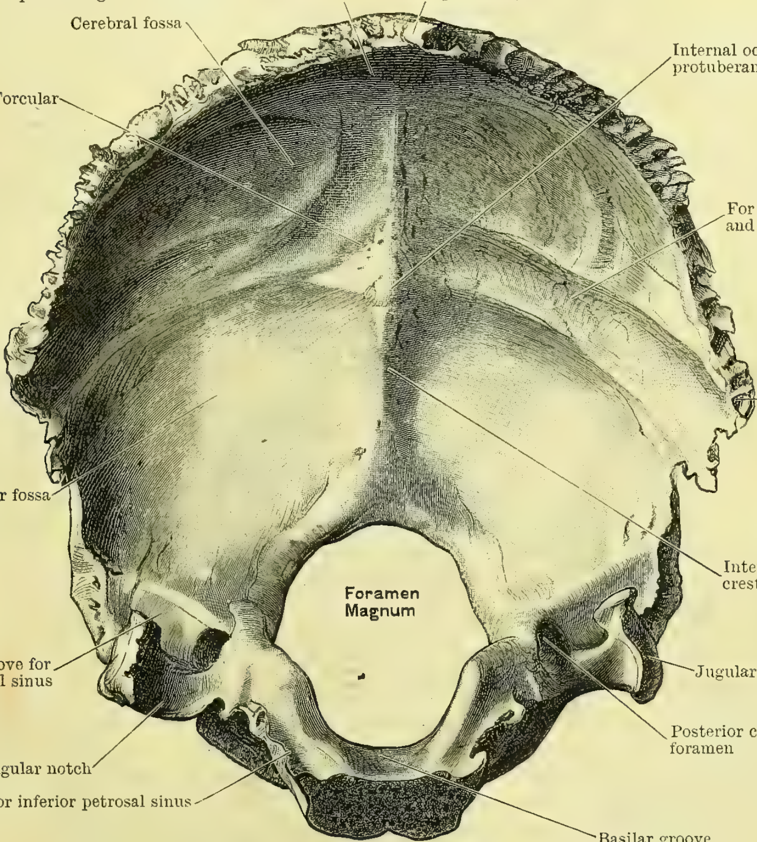


Fig. 83.—Occipital Bone (Inner Surface).

internal occipital protuberance there is usually a well-marked ridge, to one or other side of which, more frequently the right (with the bone in the normal position and viewed from behind), there is a well-defined groove, the **sulcus sagittalis**, the outer lip of which is generally less prominent. Placed in this groove is the superior longitudinal venous sinus, and attached to the lips is the falx cerebri. At right angles to the foregoing, and at the level of the internal occipital protuberance, with which they become confluent, are two transverse grooves, the sulci transversi. These grooves, which have more or less prominent edges, lie between the upper and lower pairs of fossæ, and serve for the attachment of the tentorium cerebelli as well as the lodgment of the lateral blood-sinuses. Commonly the right lateral groove is confluent with the groove to the right side of the median ridge, but exceptions to this rule are not infrequent. The angle formed by the union of the venous sinuses lodged in these grooves constitutes the torcular Herophili, which may accordingly

be placed to one or other side of the internal occipital protuberance, more frequently the right; in some cases, however, it may occupy a central position.

The *superior angle*, more or less sharp and pointed, is wedged in between the two parietal bones, its position corresponding to the site of the posterior fontanelle. The *lateral angle* articulates on either side with the posterior extremity of the mastoid portion of the temporal bone. The *superior borders*, much serrated, articulate with the parietal bones forming the **lambdoid suture**; and the *lateral edges*, extending from the external angles to the jugular process inferiorly, are connected with the inner sides of the mastoid portions of the temporals.

The **lateral** or **condylic parts** of the occipital bone (partes laterales) are placed on either side of the foramen magnum; on their under surface they bear the condyles (condyli occipitales) by means of which the skull articulates with the atlas vertebra. Of elongated oval form, the condyles are so disposed that their anterior extremities, in line with the anterior margin of the foramen magnum, lie closer together than their posterior ends, which extend as far back as the middle of the external borders of the foramen. Convex from before backwards, they are skewed so that their surfaces, which are nearly plane from side to side, are directed slightly outwards. Each is supported on a boss of bone, pierced by the **anterior condylic foramen** (canalis hypoglossi), which opens obliquely from within outwards and forwards on the floor of a fossa called the **anterior condylic fossa,** situated just external to the fore part of the condyle. The foramen transmits the hypoglossal or XII. cranial nerve, together with a meningeal branch of the ascending pharyngeal artery and its companion veins. Behind the condyle is placed the **posterior condylic fossa,** in the floor of which the **posterior condylic foramen** frequently opens. Through this a vein passes which joins the lateral sinus. The edge of the foramen magnum immediately behind the condyle is often grooved for the passage of the vertebral artery around it. Jutting out from the posterior half of the condyle is a stout bar of bone, serially homologous with the vertebral transverse process—this is the **jugular process** (processus jugularis); deeply notched in front, its anterior border is free and rounded, and forms the posterior boundary of the jugular foramen. Curving outwards from this margin, in line with the anterior condylic foramen, there is often a small pointed projection, the **processus intra-jugulare,** which serves to divide the jugular foramen into two compartments. Externally the jugular process articulates by means of a synchondrosis with the jugular surface of the petrous part of the temporal bone. Its posterior border is confluent with the lower and lateral portion of the occipital squama, and its under surface is rough and tubercular for the attachment of the rectus capitis lateralis muscle. The *superior aspect* of the lateral part displays on either side of the foramen magnum an elevated surface of oval form, the **tuberculum jugulare**; this corresponds to the part of the bone which bridges over the canal for the hypoglossal nerve. Its upper surface in many instances displays an oblique groove running across it; in this are lodged the glosso-pharyngeal, vagus, and accessory nerves. The jugular process is deeply grooved above for the lower part of the lateral blood sinus, which here turns round the anterior free edge of the process into the jugular foramen. Joining this, close to its inner edge, is the opening of the posterior condylic foramen when that canal exists.

The **basilar part** of the occipital bone (pars basilaris) extends forwards and upwards from the foramen magnum. Its anterior extremity is usually sawn across, as after adult life it is necessary to sever it in this way from the sphenoid, the cartilage uniting the two bones having by that time become completely ossified. Broad and thin behind, it narrows and thickens anteriorly, where on section it displays a quadrilateral form. Projecting from its under surface some little distance in front of the foramen magnum is the **pharyngeal tubercle** (tuberculum pharyngeum) to which the fibrous raphe of the pharynx is attached; on either side of this the rectus capitis anticus major and minor muscles are inserted. The *upper surface* forms a broad and shallow groove which slopes upwards and forwards from the thin anterior margin of the foramen magnum; in this rests the medulla oblongata. On either side its lateral edges are faintly grooved for the inferior petrosal venous sinuses, below which the lateral aspect of the bone is rough for the

cartilage which unites it to the sides and apex of the petrous part of the temporal bone.

The **foramen magnum,** of oval shape, so disposed that its long axis lies in the sagittal plane, is of variable size and form. The plane of its outlet differs somewhat in individual skulls; in most instances it is directed downwards and slightly forwards. In front the condyles encroach upon it, and narrow to some extent its transverse diameter. To its margins are attached the ligaments which unite it with the atlas and axis. Through it pass the lower part of the medulla oblongata where it becomes continuous with the spinal cord, the two vertebral arteries, the spinal accessory nerves, and the blood vessels of the meninges of the upper part of the cord.

Connexions.—The occipital bone articulates with the two parietals in front and above, with the sphenoid in front and below, with the two temporals on either side, and with the atlas vertebra by means of its condyles.

Architecture.—The squamous part displays thickenings in the position of the various ridges and crests, the stoutest part corresponding to the internal and external occipital protuberances, though it should be noted that the two protuberances do not necessarily coincide, the internal being, as a rule, placed at a higher level than the external. If the bone be held up to the light it will be at once apparent that it is much thinner where it forms the floor of the inferior fossæ than in the upper part. The basilar portion consists of a spongy core surrounded by a more compact outer envelope, thickest on its lower surface. In the condyles the spongy tissue is arranged radially to their convex articular surfaces, the hypoglossal canal being surrounded by particularly dense and compact bone.

Variations.—The most striking of the many variations to which this bone is subject is the separation of the upper part of the occipital squama to form an independent bone—the interparietal bone, called also, from the frequency of its occurrence in Peruvian skulls, the os Incæ. As will be seen below (see ossification), the occurrence of this anomaly is explained developmentally. In place of forming a single bone the interparietal is occasionally met with in two symmetrical halves, and instances have been recorded of its occurrence in three or even four pieces. In the latter cases the two anterior parts form the pre-interparietals. The articular surface of the condyles is sometimes divided into an anterior and posterior part. The so-called third occipital condyle is an outstanding process rising from the anterior border of the foramen magnum, the extremity of which articulates with the odontoid process of the axis. Springing from the under surface of the extremity of the jugular process, a rough or smooth elevated surface, or else a projecting process, the extremity of which may articulate with the transverse process of the atlas, is sometimes met with. This is the paroccipital or paramastoid process. Numerous instances of fusion of the atlas with the occipital bone have been recorded. Many are, no doubt, pathological in their origin; others are associated with errors in development. Interesting anomalies are these in which there is evidence of the intercalation of a new vertebral element between the atlas and occipital, constituting what is termed a proatlas.

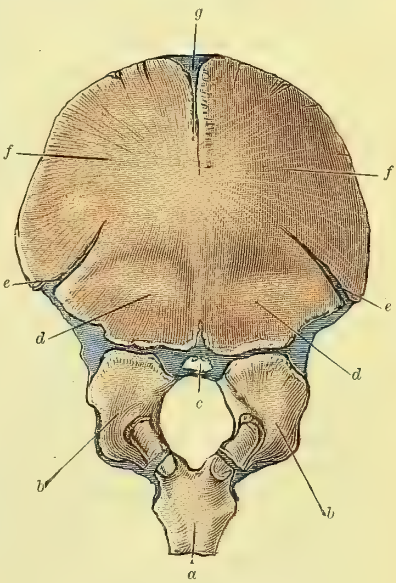


Fig. 84.—Ossification of Occipital Bone.

a, Basilar centre; *b*, Exoccipital; *c*, Ossicle of Kerkring; *d*, Supra-occipital (from cartilage); *e*, Fissure between supra-occipital and interparietal; *f*, Interparietal (from membrane); *g*, Fissure between interparietals.

Ossification.—The major part of the bone ossifies in cartilage, the upper part of the squama (interparietal), alone developing in membrane. The **basilar part** begins to ossify about the sixth week of fœtal life by the appearance of two centres, one in front of the other; the anterior, according to Albrecht, constitutes the basiotic, the posterior the basioccipital. These two centres—which there is some reason to believe—may themselves be formed by the fusion of pairs placed laterally, rapidly unite, so that the occurrence of one centre alone is frequently described. From this the fore part of the margin of the foramen magnum is formed, together with a portion of the anterior end of the occipital condyle on either side. It helps also to close up the front of the anterior condylic canal. Union with the condylic parts is complete about the fourth or fifth year. Ankylosis between the basioccipital and the sphenoid takes place about the twenty-fifth year.

The **lateral, condylic,** or **exoccipital parts** begin to ossify from a single centre about

the end of the second month of fœtal life. The notch for the hypoglossal canal appears about the third month. From this centre is formed the posterior three-fourths of the occipital condyle. The exoccipital is usually completely fused with the squama by the third year or earlier.

As already noted, the squama consists of two parts—the one above the occipital crest, the other below it; the former develops in membrane, the latter in cartilage. In a three-months fœtus this difference is very characteristic. The cartilaginous part (supra-occipital) begins to ossify from two centres about the sixth or seventh week, which rapidly join to form an elongated strip placed transversely in the region of the occipital protuberance. The centres for the upper part (interparietal) appear later. According to Maggi (*Arch. Ital. Biol.* tome 26, fas. 2, p. 301), they are four in number, of which two placed on either side of the middle line appear about the second month. The other pair, placed laterally, are seen about the third month; fusion between these takes place early, but their disposition and arrangement explain the anomalies to which this part of the bone is subject. The mesial pair may persist as separate ossicles, or fuse to form the pre-interparietals, whilst the lateral pair may remain independent of the supraoccipital as a single or double interparietal bone. Union between the supraoccipital and the inter-parietal elements occurs about the third or fourth month; but evidence of their separation is frequently met with even in the adult by the persistence of a transverse suture running inwards from each external angle of the squama, or, as above mentioned, there may be an os Incæ. The supraoccipital forms a small part of the middle of the hinder border of the foramen magnum, though here a small independent centre, known as the ossicle of Kerkring, is occasionally met with. Other independent centres are sometimes seen between the supraoccipital and the exoccipitals.

At birth the occipital consists of four parts—the interparietal and supraoccipital combined, the basioccipital, and the exoccipitals—one on either side.

The Temporal Bones.

The **temporal bone** (os temporale) lies about the centre of the lower half of either side of the skull, and enters largely into the formation of the cranial base. It is placed between the occipital behind, the parietal above, the sphenoid in front, and the occipital and sphenoid internally and below. At birth it consists of three parts—an upper and outer part, the **squamous** or **squamo-zygomatic portion**; an inner and posterior portion, the **petro-mastoid,** which contains the organ of hearing, together with that specially associated with equilibration; and an under or **tympanic part,** from which the floor and anterior wall of the external auditory meatus is formed.

The **squamous part** (pars squamosa) consists of a thin shell-like plate of bone placed vertically, having an inner (cerebral) and an outer (temporal) surface and a semicircular upper border. Inferiorly, behind, and internally it is fused in early life with the petro-mastoid portion by means of the squamoso-mastoid and the petro-squamosal sutures, traces of which are often met with in the adult bone; whilst below and in front it is separated from the tympanic and petrous parts by the **Glaserian fissure.** Its *external surface,* smooth and slightly convex, enters into the formation of the floor of the temporal fossa, and affords attachment to the temporal muscle. Near its hinder part it is crossed by one or more ascending grooves for the branches of the middle temporal artery. In front and below there springs from it the **zygomatic process** (processus zygomaticus). This arises by a broad attachment, the surfaces of which are inferior and superior; curving outwards and forwards, it then becomes twisted and narrow so that its sides are turned inwards and outwards and its edges directed upwards and downwards. Anteriorly it ends in an oblique serrated extremity which articulates with the zygomatic process of the malar bone. Posteriorly the edges of this process separate and are termed its roots. The upper edge, which becomes the **posterior root,** sweeps back over the external auditory meatus, and is confluent with a ridge, the **supra-mastoid crest,** which curves backwards and slightly upwards, and serves to define the limit of the temporal fossa posteriorly. The inferior edge turns inwards and constitutes the **anterior root**; the under surface of this forms a transversely-placed rounded ridge, the **articular eminence** (tuberculum articulare), behind which there is a deep

hollow, the **glenoid fossa** (fossa mandibularis), limited posteriorly by the tympanic plate, and crossed at its deepest part by an oblique fissure, the **Glaserian fissure** (fissura petro-tympanica). This cleft, which is closed externally, transmits about its middle the tympanic branches of the internal maxillary artery, and lodges the slender process of the malleus. At its inner end the lips of this fissure are frequently separated by a thin scale of bone, a downgrowth from the tegmen tympani of the petrous part, which here separates the tympanic from the squamous elements, forming in its descent the major part of the outer wall of the osseous Eustachian canal, which lies immediately internal to it. Between this scale of bone and the posterior edge of the fissure there is a small canal (**canal of Huguier**), which transmits the chorda tympani nerve. The part of the glenoid fossa in front of the fissure articulates with the condyle of the inferior maxilla, through the medium of the interarticular cartilage, which is here interposed and rests as well on the tuberculum articulare. Anteriorly the part of the fossa behind the fissure is non-

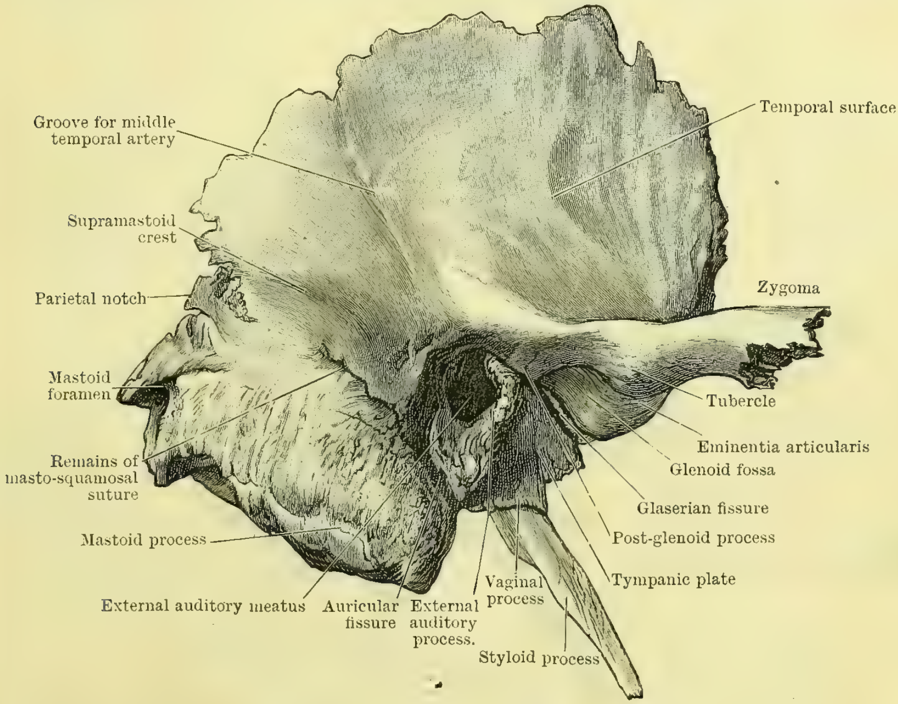


FIG. 85.—RIGHT TEMPORAL BONE AS SEEN FROM THE OUTER SIDE.

articular and lodges a portion of the parotid gland. At the angle formed by the divergence of the two roots of the zygoma, in correspondence with the outer part of the articular eminence, there is a rounded **tubercle**; to this are attached the fibres of the external lateral ligament of the temporo-mandibular joint. In front of the inner end of the articular eminence there is a small triangular surface, limited in front by the edge of the anterior root, and internally by a thick serrated margin which articulates with the outer side of the great wing of the sphenoid; this area forms part of the roof of the zygomatic fossa. Just anterior to the external auditory meatus and projecting downwards from the under surface of the posterior root there is a conical process, called the **post-glenoid tubercle**, which forms a prominent anterior lip to the external extremity of the Glaserian fissure; it is the representative in man of a process which occurs in some mammals and prevents the backward displacement of the lower jaw. By some anatomists it is referred to as the **middle root** of the zygoma.

The **zygomatic process** by its lower margin and inner surface gives origin to the masseter muscle, whilst attached to its upper edge are the layers of the temporal fascia. Behind the external auditory meatus, and below the supramastoid crest, the squamous element extends downwards as a pointed process, which assists in forming

the roof and posterior wall of the external auditory meatus, where it unites inferiorly with the tympanic plate. In the adult this process is occasionally sharply defined posteriorly by an oblique irregular fissure, the remains of the masto-squamosal suture.

Professor Macewen has pointed out that this suture frequently remains open till puberty and occasionally after, and may be of importance as a channel along which infective processes may extend.

The *inner surface* of the squamous part, less extensive than the outer aspect owing to the bevelling of the superior border, is marked by the impression of the convolutions of the temporal lobe of the cerebrum, and is limited below by the petro-squamosal suture, the remains of which can frequently be seen. It is crossed in front by an ascending groove for the middle meningeal artery, branches from which course backwards over the bone in grooves more or less parallel to its upper border.

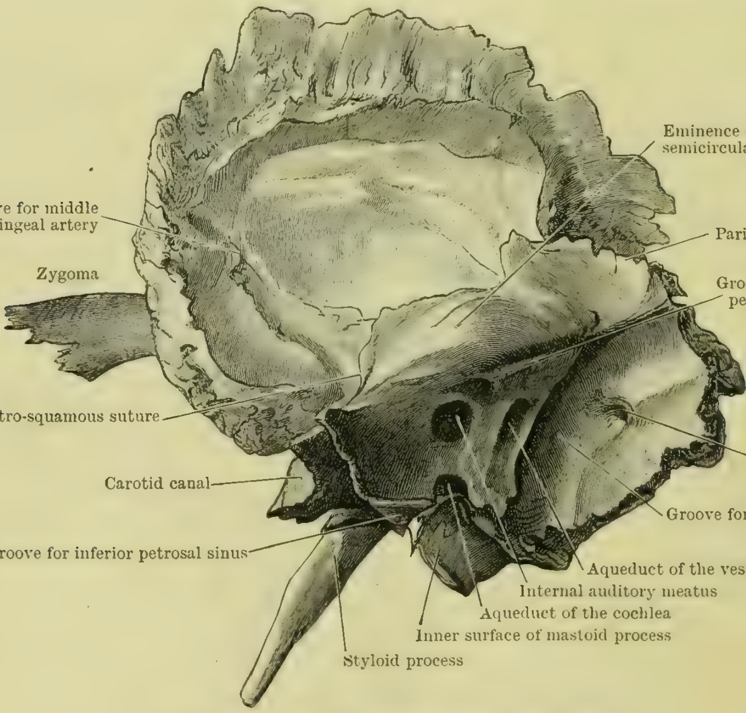


FIG. 86.—RIGHT TEMPORAL BONE (Inner Side).

The *superior border* of the squamous part is curved, sharp, and scale-like, being bevelled at the expense of its inner table, except in front, where the margin is thick and stout. Here it articulates with the great wing of the sphenoid, its union with that bone extending to near the fore part of the summit of the curve, behind which it is united to the parietal overlapping the lower border of that bone; posteriorly the free margin of the squamous part ends at an angle formed between it and the mastoid process called the **incisura parietalis.**

The **tympanic part** (pars tympanica) of the temporal bone forms the anterior, lower, and part of the posterior wall of the external auditory meatus. Bounded in front and above by the Glaserian fissure, it forms the hinder wall of the non-articular part of the glenoid fossa. Fused internally with the petrous part, its lower edge, sharp and well defined internally, splits to enclose the root of the projecting **styloid process**, and is hence called the **vaginal process.** Externally it unites with the fore part of the mastoid process, and higher up with the descending process of the squamous part, from both of which it is separated by the **auricular fissure** (fissura tympano-mastoidea) through which the auricular branch of the vagus escapes. Its free border, which forms the anterior, lower, and part of the

posterior border of the external auditory meatus, is usually somewhat thickened and rough, and serves for the attachment of the cartilaginous part of the canal.

The **external auditory meatus** (meatus acusticus externus) is directed obliquely inwards and a little forwards, and describes a slight curve, the convexity of which is directed upwards; of oval form, its long axis, near its orifice, is nearly vertical, but, as it passes inwards, inclines somewhat forwards so as to give a twist to the canal. The upper margin of the outer orifice overhangs considerably the lower edge, but owing to the obliquity of the inner aperture, to which the membrana tympani is attached, the upper and lower walls of the osseous canal are nearly equal in length.

The **petro-mastoid part** (pars petrosa et mastoidea) of the temporal bone, of pyramidal form, is fused to the inner aspect of the tympanic and squamosal portions, extending behind them, however, to form the well-marked and prominent **mastoid process,** which lies posterior to the external auditory meatus. This process (pars mastoidea) forms a nipple-like projection, the size of which differs considerably in different individuals. Usually larger in the male than in the female, its rough outer surface and lower border serve for the insertions of the sterno-mastoid, trachelo-mastoid, and splenius capitis muscles. Within and below its pointed extremity there is a deep groove (incisura mastoidea), usually well marked, which gives origin to the posterior belly of the digastric muscle; whilst lying to the inner side of this, and separated from it, by a more or less well-defined rough ridge, there can oftentimes be seen a narrow, shallow furrow, which indicates the course of the occipital artery. The **inner surface** of the mastoid portion forms, in part, the lateral wall of the posterior cranial fossa, in which the cerebellar lobes are lodged. Coursing across this aspect of the bone there is a broad curved groove, the convexity of which is directed forwards and lies in the angle formed by the base of the petrous part, and its fusion with the mastoid portion. The depth to which the bone is here channelled varies considerably, and is important from a surgical standpoint, as herein lies the sigmoid portion of the lateral venous sinus. Anteriorly the mastoid is fused with the descending process of the squamosal above, and below, where it is united with the tympanic, it enters into the formation of the posterior wall of the external auditory meatus and the cavity of the tympanum. Above, its free margin is rough and serrated, and articulates with the posterior inferior angle of the parietal; behind and below it articulates by a jagged suture with the occipital. Traversing this suture, or near it, is the **mastoid foramen** (foramen mastoideum), which transmits a vein from the lateral sinus to the cutaneous occipital vein.

The **petrous part** of the petro-mastoid is of the form of an elongated three-sided pyramid. By its base it is united obliquely to the inner sides of the squamosal and tympanic parts. Its apex is directed inwards, forwards, and a little upwards. Its three surfaces are arranged as follows:—The *superior* or *anterior* looks upwards, slightly forwards, and a little outwards, and forms part of the floor of the middle cranial fossa. The *posterior* is directed backwards and inwards, and forms part of the anterior wall of the posterior cranial fossa. The *inferior* is seen on the under surface of the base of the skull, and is directed downwards. The borders are named respectively anterior, superior, and posterior.

The *anterior border* is short, and forms an acute angle with the fore part of the squamous part within which is received the spinous part of the great wing of the sphenoid. Here, too, the osseous **Eustachian canal** (canalis musculotubarius) may be seen leading backwards and outwards from the summit of the angle to reach the fore part of the cavity of the tympanum. On looking into it, the canal is seen to be divided into two unequal parts by an osseous partition, the **cochleariform process** (septum tubæ). The upper compartment, the smaller of the two (semicanalis m. tensoris tympani), lodges the tensor tympani muscle, whilst the lower (semicanalis tubæ auditivæ) forms the osseous part of a channel (the **Eustachian tube**), which serves to conduct air from the pharynx to the tympanum.

The *posterior border* is in part articular and in part non-articular. Posteriorly and externally it corresponds to the upper margin of an area on the inferior surface with which the extremity of the jugular process of the exoccipital articulates. In front of that it is irregularly notched, and forms the free anterior edge of the

jugular foramen, internal to which it has a sharp curved border, often grooved, reaching to the apex. This groove, which is completed by articulation with the outer side of the basioccipital, lodges the inferior petrosal venous sinus.

The *superior border* is a twisted edge which is continuous with the upper margin of the groove for the lateral sinus posteriorly, and anteriorly and internally reaches the apex of the bone. Running along it there is usually a well-marked groove for the superior petrosal venous sinus, and near its inner extremity it is slightly notched for the passage of the trigeminal nerve. Along the entire length of this border the tentorium cerebelli is attached.

On the *inferior surface* of the petrous part, which is bounded in front by the anterior border internally and the tympanic plate externally, and behind by the posterior border, the following structures are to be noted. Springing from and ensheathed by the vaginal process is the slender and pointed **styloid process** (processus styloideus), the length of which varies much. Projecting downwards and slightly forwards and inwards, it affords attachments to the stylo-glossus, stylo-hyoid, and stylo-pharyngeus muscles as well as the stylo-hyoid and stylo-mandibular ligaments. Just behind it, and between it and the mastoid process, is the **stylo-mastoid foramen** (foramen stylomastoideum), which lies at the anterior end of the digastric groove, and transmits the facial nerve and the stylo-mastoid artery. Immediately within the styloid process there is a deep, smooth, excavated hollow, the **jugular fossa** (fossa jugularis), which is converted into a foramen (jugular) by articulation with the occipital bone. Behind and external to the fossa there is a small **quadrilateral surface**, which is united to the extremity of the jugular process of the exoccipital by a synchondrosis. Inside the fossa, on its outer aspect, or placed on its external border, is the opening of a small canal (canaliculus mastoideus), which passes outwards to open into the canalis facialis, and transmits the auricular branch of the vagus (Arnold's nerve), which ultimately escapes through the auricular fissure (see *ante*). In front of the jugular fossa and separated from it by a sharp crest, and just internal to the tympanic plate, is the circular opening of the inferior orifice of the **carotid canal** (canalis caroticus). Directed at first upwards, this canal bends at a right angle and turns forwards and inwards, lying parallel to the anterior border; reaching the fore part of the apex of the bone, it opens in front by an oblique ragged orifice. Through the canal the internal carotid artery, accompanied by a plexus of sympathetic nerves, passes into the cranium. On the ridge of bone separating the jugular fossa from the carotid canal is the opening of a small canal (canaliculus tympanicus), through which the tympanic branch of the glosso-pharyngeal (nerve of Jacobson) passes to reach the tympanum. Within the orifice of the carotid canal another small opening or openings (canaliculi carotici tympanici) may be noticed which afford passage to the tympanic branches of the internal carotid artery and carotid

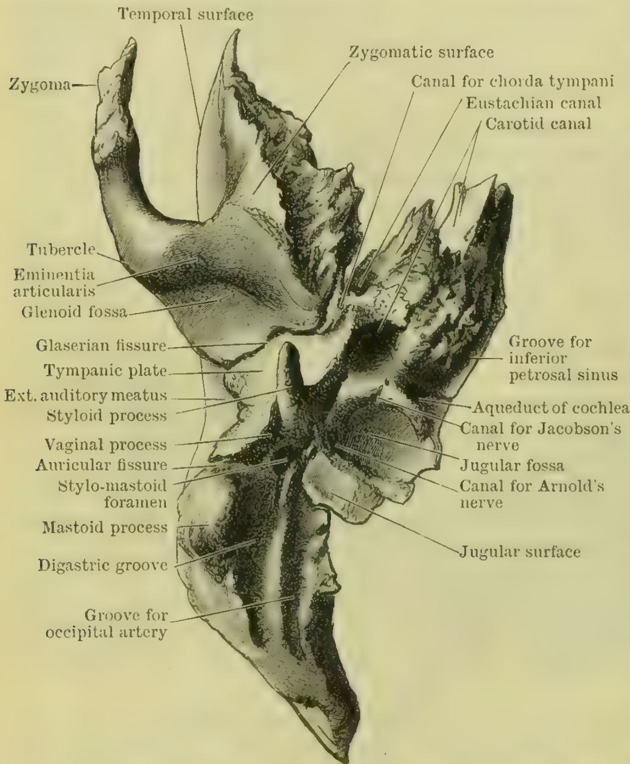


FIG. 87.—RIGHT TEMPORAL BONE AS SEEN FROM BELOW.

sympathetic plexus. In front of the jugular fossa, and internal to the orifice of the carotid canal, there is a V-shaped depression (fossula fenestræ cochleæ), on the floor of which and close to the posterior border is the orifice of the **aqueduct** of the **cochlea** (apertura externa aquæductus cochleæ). In the fossa is lodged the petrous ganglion of the glosso-pharyngeal nerve, and the aqueduct transmits a tubular prolongation of the dura mater, which forms a channel of communication between the perilymph of the cochlea and the subarachnoid space. A small vein also passes through it. In front of and internal to the orifice of the carotid canal the under surface of the apex of the bone corresponds to a rough quadrilateral surface which forms the floor of the carotid canal, and also serves for the attachment of the cartilaginous part of the Eustachian tube as well as the origin of the levator palati muscle; elsewhere it has attached to it the dense fibrous tissue which fills up the cleft (petro-basilar fissure) between it and the basilar process of the occipital bone.

The *superior* or *anterior surface* bears the impress of the convolutions of the under surface of the temporal lobe of the cerebrum, which rests upon it; in addition, however, a distinct but shallow depression (impressio trigemini) near the apex, corresponding to the roof of the carotid canal, can be seen; in this is lodged the Gasserian ganglion on the sensory root of the V. cranial nerve. External to the middle of the upper surface, and close to its posterior border, is the elevation (eminentia arcuata), more or less pronounced, which marks the position of the superior semicircular canal here lodged within the bone. A little in front of this, and in line with the angle formed by the anterior border and the squamous part, is the slit-like opening of the **hiatus Fallopii** (hiatus canalis facialis), within the projecting lip of which two small orifices can usually be seen. These are the openings of the **aquæductus Fallopii** (canalis facialis); if a bristle be passed through the inner of the two openings it will be observed to pass into the bottom of the internal auditory meatus, if into the outer, it will pass through the aqueduct of Fallopius, and, provided the channel be clear, will appear on the under surface of the bone at the stylomastoid foramen. Leading forwards and inwards from the hiatus towards the anterior border is a groove; in this lies the great superficial petrosal nerve which passes out of the hiatus. A small branch of the middle meningeal artery also enters the bone here. A little external to the hiatus is another small opening (apertura superior canalis tympanici), often difficult to see; from this a groove runs forwards which channels the upper surface of the roof of the canal for the tensor tympani muscle. Through this foramen and along this groove passes the lesser superficial petrosal nerve. Behind this, and in front of the **arcuate eminence,** the bone is usually thin (as may be seen by holding it up to the light falling through the external auditory meatus), roofing-in the cavity of the tympanum and forming the **tegmen tympani.** Externally the line of fusion of the petrous with the squamous part is often indicated by a faint and irregular petro-squamous fissure.

The most conspicuous object on the *posterior surface* of the petrous part of the bone is the **internal auditory meatus** (meatus acusticus internus), which has an oblique oval aperture and leads outwards and slightly downwards into the substance of the bone, giving passage to the auditory and facial nerves, together with the pars intermedia. The canal appears to end blindly; but if it be large, or still better, if part of it be cut away, its fundus will be seen to be crossed by a horizontal ridge, the **falciform crest,** which divides it into two fossæ, the floors of which (laminæ cribrosæ) are pierced by numerous small foramina for the branches of the auditory nerve and the vessels passing to the membranous labyrinth, whilst in the fore and upper part of the higher fossa the orifice of the **Fallopian aqueduct** (canalis facialis), through which the facial nerve passes, is seen leading in the direction of the hiatus Fallopii (see *ante*). External to the internal auditory meatus and above it, close to the superior border, an irregular depression, often faintly marked, with one or two small foramina opening into it, is to be noticed. This is the **floccular fossa** (fossa subarcuata), best seen in young bones, where it forms a distinct recess, which is bounded above by the bulging caused by the superior semicircular canal, within the concavity of which it is placed; it lodges a process of the dura mater. Below and external to this, separated from it by a smooth, elevated curved ridge, is the opening of the **aqueduct of the vestibule** (apertura externa aquæductus vestibuli), often concealed

8 *a*

in a narrow curved fissure overhung by a sharp scale of bone. In this is lodged the ductus endolymphaticus. The ridge above it corresponds to the upper half of the posterior semicircular canal.

Connexions.—The temporal bone articulates with the malar, sphenoid, parietal, and occipital bones, and by a movable joint with the inferior maxilla. Occasionally the temporal articulates with the frontal, as happens normally in the anthropoid apes; although the region of the pterion is characterised by an X-like form in the lower races of man there is no evidence that the occurrence of a fronto-squamosal suture is more frequent in the lower than the higher races, its occurrence being due to the manner of fusion of the so-called epipteric ossicles with the surrounding bones.

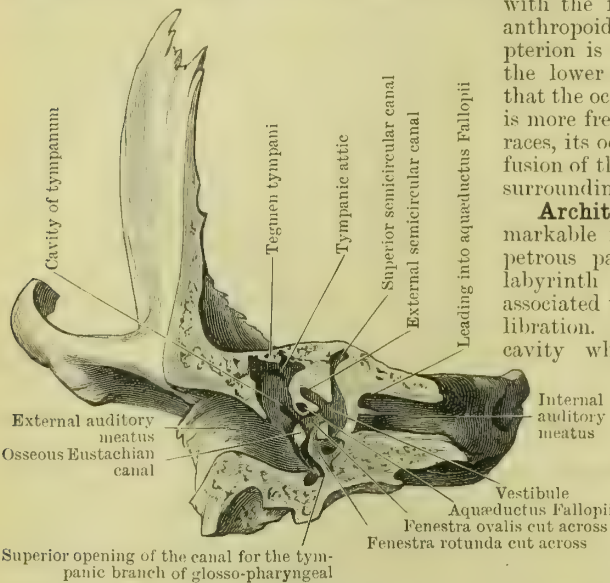


FIG. 88.—VERTICAL TRANSVERSE SECTION THROUGH LEFT TEMPORAL BONE (Anterior Half of Section).

Architecture.—The temporal bone is remarkable for the hardness and density of its petrous part, wherein is lodged the osseous labyrinth which contains the delicate organs associated with the senses of hearing and equilibration. The **middle ear** or **tympanum** is a cavity which contains the small auditory ossicles and is separated from the external auditory meatus by the membrana tympani. *In front* it communicates with the pharynx by the Eustachian tube; *behind*, it opens into the mastoid antrum and mastoid air-cells by the aditus ad antrum. *Superiorly*, it is separated from the middle cranial fossa by a thin plate of bone called the tegmen tympani. *Inferiorly*, its floor is formed in part by the roof of the jugular fossa and the carotid canal. *Internally*, it is related to the structures which form the inner ear, notably the **cochlea** and **vestibule**, in front of which it is separated by a thin plate of bone from the carotid canal. Curving over the cavity of the tympanum is the aquæductus Fallopii, the thin walls of which are occasionally deficient. These details will be further dealt with in the section devoted to the Organs of Sense.

Variations.—The occurrence of a deficiency in the floor of the external auditory meatus is not uncommon in the adult. It is met with commonly in the child till about the age of five, and is due to incomplete ossification of the tympanic plate. The line of the petro-squamosal suture is occasionally grooved for the lodgment of a sinus (petro-squamosal); sometimes the posterior end of this is continuous with a canal which pierces the superior border of the bone and opens into the lateral sinus. Anteriorly the groove may pass into a canal which pierces the root of the zygoma and appears externally above the external extremity of the Glaserian fissure. These are the remains of channels through which the blood passed in the fœtal condition (see *ante*). Symington has described a case in which the squamous part was distinct and separate from the rest of the temporal bone in an adult; whilst Hyrtl has observed the division of the temporal squama into two by a transverse suture.

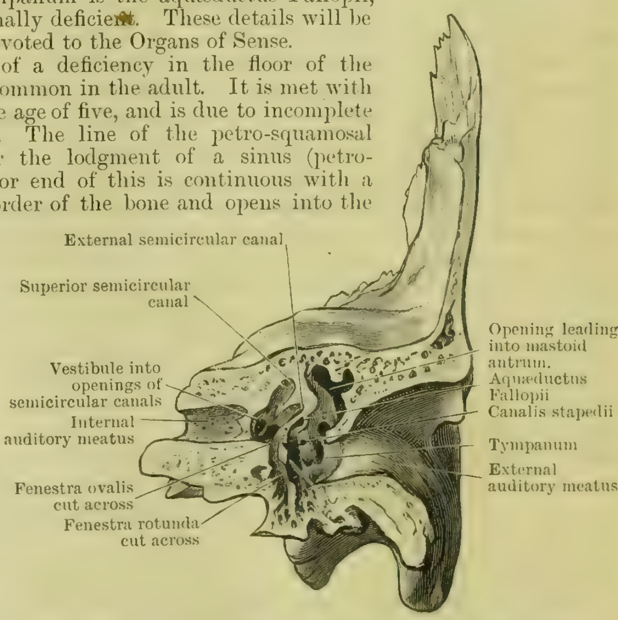


FIG. 89.—VERTICAL TRANSVERSE SECTION THROUGH LEFT TEMPORAL BONE (Posterior Half of Section).

Ossification.—The petro-mastoid portion of the bone is developed by the deposition of earthy matter in the cartilaginous ear capsule and the perichondrium lining the labyrinth. The squamous and tympanic parts are ossified in membrane.

Ossification commences in the ear capsule in the fifth month, and proceeds so rapidly

that by the end of the sixth month the individual centres are more or less fused. Of these, one which appears in the vicinity of the eminentia arcuata is the most definite in position and form; from this a lamina of bone of spiral form is developed, which covers in the inner limb of the superior semicircular canal, and forms the roof of the internal auditory meatus, together with the commencement of the Fallopian aqueduct. Reaching forwards, it extends to the apex of the petrous part; whilst externally it forms part of the inner wall of the tympanum, surrounds the fenestra ovalis, and encloses within its substance portions of the cochlea, vestibule, and superior semicircular canal. Another centre appears in the vicinity of the promontory on the inner wall of the tympanum, surrounds the fenestra rotunda, forms the floor of the vestibule, and extends inwards to complete the floor of the internal auditory meatus. Surrounding the cochlea inferiorly and externally, it completes the floor of the tympanum, and ultimately blends with the fore and under part of the tympanic ring. The carotid canal at first grooves it, and is then subsequently surrounded by it. According to Lambertz the lamina spiralis of the cochlea ossifies in membrane. The roof of the tympanum is formed from a separate centre, which extends backwards towards the superior semicircular canal, and encloses the tympanic part of the aqueduct of Fallopius; externally this centre unites by suture with the squamosal, and sends down a thin process, which appears between the lips of the Glaserian fissure, and forms the outer wall of the Eustachian tube. Nuclei, either single or multiple, appear in the base of the petrous part, and envelop the posterior and external semicircular canals. It is by extension from this part that the mastoid process is ultimately developed. To these centres the terms pro-otic, opisthotic, pterotic, and epiotic, respectively, have been applied by Huxley and others. The **styloid process**, an independent development from the upper end of the cartilage of the second visceral arch, is ossified from two centres. The upper or basal appears before birth, and rapidly unites with the petromastoid, the tympanic plate encircling it in front. This represents the **tympanohyal** of comparative anatomy. At birth, or subsequent to it, another centre appears in the cartilage below the above: this is the **stylohyal.** Ankylosis usually occurs in adult life between the tympanohyal and stylohyal, the union of the two constituting the so-called styloid process of human anatomy.

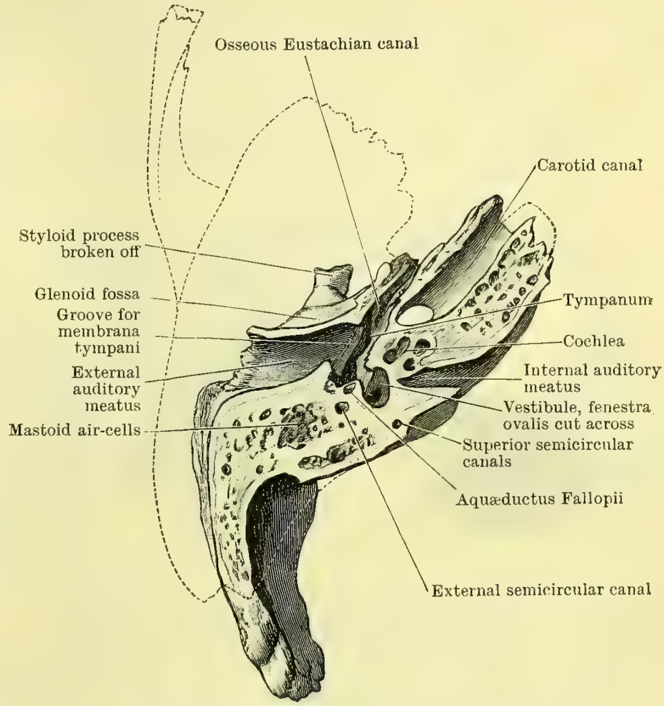


FIG. 90.—HORIZONTAL SECTION THROUGH LEFT TEMPORAL BONE (Lower Half of Section).

The centre from which the **squamo-zygomatic** develops appears in membrane about the end of the second month. Situated near the root of the zygoma, it extends forwards and outwards into that process, inwards to form the floor of the glenoid fossa, and upwards into the squamosal. From this latter there is a downward and backward extension, which forms the post-auditory process; this ultimately blends with the posterior limb of the tympanic ring, being separated from it in the adult by the auricular fissure. It forms the outer wall of the mastoid antrum, and constitutes the fore and upper part of the mastoid process in the adult. About the third month a centre appears in the outer membranous wall of the tympanum: from this the **tympanic ring** is developed. Incomplete above, it displays two free extremities. Of these, the anterior is somewhat enlarged, and unites in front with the glenoid portion of the squamo-zygomatic, being separated from it by the Glaserian fissure and the downgrowth from the tegmen tympani; the

posterior joins the post-auditory process of the squamo-zygomatic above mentioned. Below, it blends internally with the portion of the petro-mastoid which forms the floor of the tympanum, and ensheathes the tympanohyal behind. From the outer side of the lower part of this ring two tubercles arise; these grow outwards, and so form the floor of the external auditory meatus. The interval between them remains unossified till about the age of five or six, after which closure takes place. This deficiency may, however, persist even in adult life (see *ante*, Variations).

At birth the temporal bone can usually be separated into its component parts. The outer surface of the petrous part not only forms the inner wall of the tympanum, but is

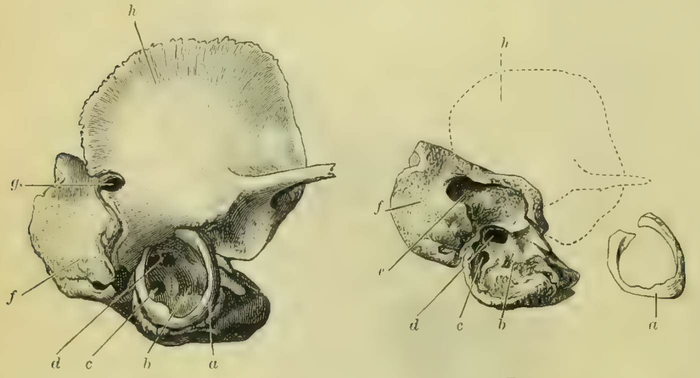


FIG. 91.—A. THE OUTER SURFACE OF THE RIGHT TEMPORAL BONE AT BIRTH. B. THE SAME WITH SQUAMO-ZYGOMATIC PORTION REMOVED.

(The lettering is the same in both A and B.) *a*, Tympanic ring. *b*, Inner wall of tympanum. *c*, Fenestra rotunda. *d*, Foramen ovale. *e*, Mastoid. *f*, Mastoid process. *g*, Masto-squamosal suture, with foramen for transmission of vessels. *h*, Squamo-zygomatic, removed in figure B to show how its descending process forms the outer wall of the mastoid antrum.

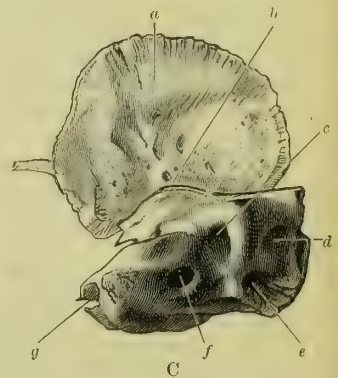


FIG. 91.—C. INNER SURFACE OF THE RIGHT TEMPORAL BONE AT BIRTH.

a, Squamo-zygomatic. *b*, Petro-squamosal suture and foramen (just above the end of the lead line). *c*, Subarcuate fossa. *d*, Aquæductus vestibuli. *e*, Aquæductus cochleæ. *f*, Internal auditory meatus. *g*, Upper end of carotid canal.

hollowed out behind and above to form the inner side of the mastoid antrum, the outer wall of which is completed by the post-auditory process of the squamo-zygomatic. As yet the mastoid process is undeveloped. It only assumes its nipple-like form about the second year. Towards puberty its cancellous tissue becomes permeated with air spaces, which are in communication with and extensions from the mastoid antrum. The external auditory meatus is unossified in front and below, the outgrowth from the tympanic ring occurring subsequent to birth. The glenoid fossa is shallow and everted; the jugular fossa is ill-marked; whilst the subarcuate fossa is represented by a deep pit, the so-called floccular fossa of comparative anatomy. The hiatus Fallopii is an open groove, displaying at either end the openings of the inner and outer portions of the Fallopian aqueduct.

THE SPHENOID BONE.

The **Sphenoid bone** (os sphenoidale) lies in front of the basioccipital mesially, and the temporals on either side. It enters into the formation of the cranial, orbital, and nasal cavities, as well as the temporal, zygomatic, pterygoid, and spheno-maxillary fossæ. It consists of a body with three pairs of expanded processes, the great wings, the lesser wings, and the pterygoid processes.

The **body** (corpus), more or less cubical in form, is hollow, and contains within it the two large **sphenoidal air sinuses**. These are separated by a partition, which is usually deflected to one or other side of the middle line. Each sinus extends outwards for a short distance into the root of the great wing, and downwards and outwards towards the base of the pterygoid process of the same side. They communicate by apertures with the upper and back part of the nasal fossæ. In the adult the *posterior aspect* of the body displays a sawn surface due to its separation from the basioccipital with which in the adult it is firmly ankylosed. The *superior surface*, from the fore angles of which the lesser wings arise, displays an appearance comparable to that of an oriental saddle. Over its middle there is a deep depression, the **sella turcica** or **pituitary fossa** (fossa hypophyseos), in which is lodged the

pituitary body. Behind, this is overhung by a sloping ridge, the **dorsum sellæ**, the posterior surface of which is inclined upwards, and is in continuation with the basilar groove of the occipital bone. Anteriorly and externally the angles of this ridge project over the pituitary fossa in the form of prominent tubercles, called the

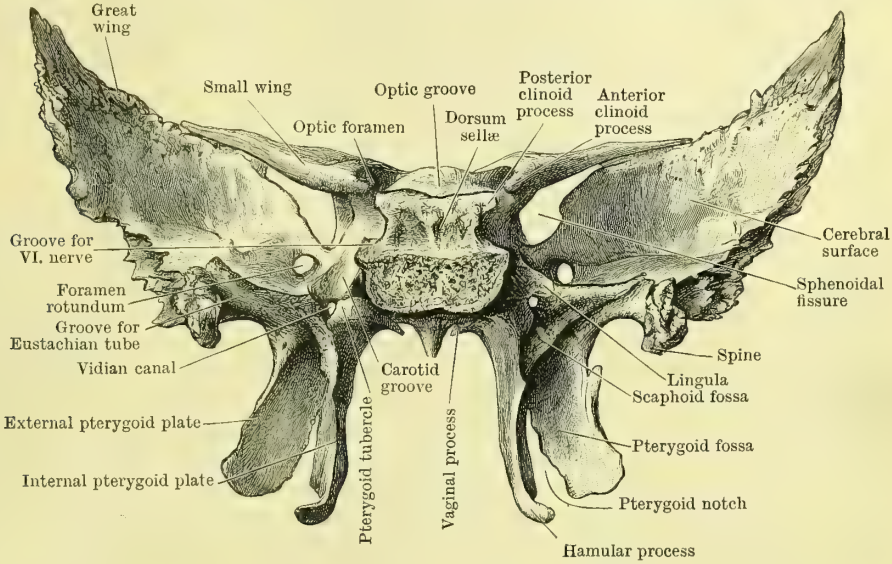


FIG. 92.—SPHENOID AS SEEN FROM BEHIND.

posterior clinoid processes (processus clinoidei posteriores). In front of the pituitary fossa there is a transverse elevation, the **olivary eminence** (tuberculum sellæ) towards the outer extremities of which, and somewhat behind, there are oftentimes little spurs of bone, the **middle clinoid processes** (processus clinoidei medii).

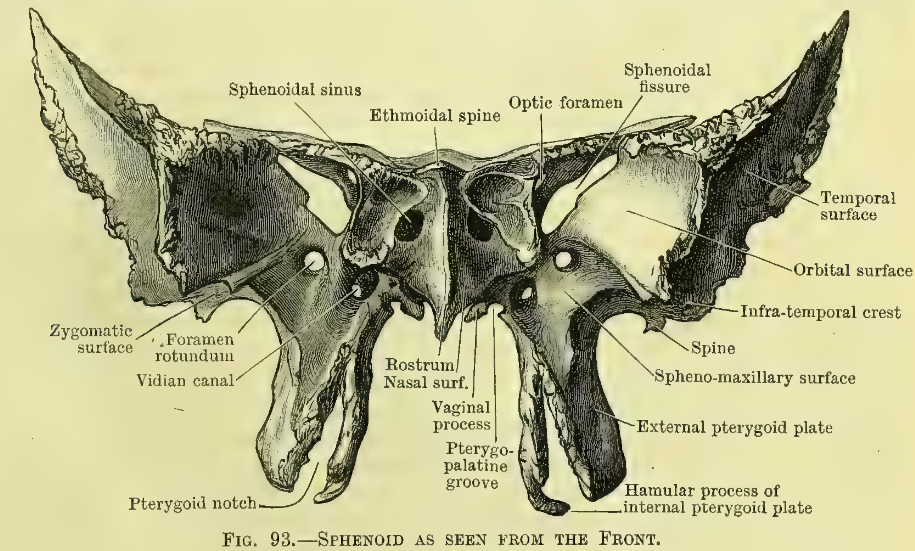


FIG. 93.—SPHENOID AS SEEN FROM THE FRONT.

In front of the olivary eminence is the **optic groove** (sulcus chiasmatis), which passes outwards on either side to become continuous, between the roots of the lesser wings, with the optic foramina.

This groove is liable to considerable variations, and apparently does not always serve for the lodgment of the optic chiasma. (Lawrence, "Proc. Soc. Anat." *Journ. Anat. and Physiol.*, vol. xxviii. p. 18.)

In front of the optic groove, from which it is often separated by a thin sharp edge, the superior surface continues forwards on the same plane as the upper surfaces of

the lesser wings, and terminates anteriorly in a ragged edge, which articulates with the cribriform plate of the ethmoid, and has often projecting from it, mesially, a pointed process, the **ethmoidal spine**. The *lateral aspects* of the body are fused with the great wings, and in part also with the roots of the pterygoid processes. Curving along the side of the body, superior to its attachment to the great wing, is an ∫-shaped groove, the **carotid groove** (sulcus caroticus), which marks the position and course of the internal carotid artery. Posteriorly, the hinder margin of this groove, formed by the salient outer edge of the posterior surface of the body, articulates with the apex of the petrous portion of the temporal bone, and is hence called the **petrosal process**; just above this, on the lateral border of the dorsum sellæ, there is often a groove for the sixth nerve.

The *anterior surface* of the body displays a vertical mesial **sphenoidal crest** (crista sphenoidalis), continuous above with the ethmoidal spine, and below with the pointed projection called the rostrum. This crest articulates in front with the perpendicular plate of the ethmoid. On either side of the middle line are seen the irregular openings leading into the sphenoidal air sinuses, the thin anterior walls of which are in part formed by the absorption of the sphenoidal turbinated bones with which in early life they are in contact. With the exception of a broad groove leading downwards from the apertures above mentioned, which enters into the formation of the roof of the nasal fossa of the corresponding side, the lateral aspects of this surface of the bone are elsewhere in articulation with the lateral masses of the ethmoid and the orbital processes of the palate bones. The **rostrum** is continued mesially for some distance along the *inferior surface* of the body, where it forms a prominent keel which fits into the recess formed by the alæ of the vomer. The edges of the latter serve to separate the rostrum from the incurved vaginal processes at the roots of the internal pterygoid plates. Posteriorly the under surface of the body of the sphenoid is rougher, and covered by the mucous membrane of the roof of the pharynx; here, occasionally, a median depression may be seen which marks the position of the inferior extremity of a fœtal channel, called the **canalis cranio-pharyngeus**.

The **lesser** or **orbital wings** (alæ parvæ) are two flattened triangular plates of bone which project forwards and outwards from the fore and upper part of the body of the bone, with which they are united by two roots, enclosing between them the **optic foramina** (foramina optica) for the transmission of the optic nerves and ophthalmic arteries. Of these roots, the posterior springs from the body just wide of the olivary eminence, separating the carotid groove behind from the optic foramen in front; externally this root is confluent with the recurved posterior angle of the lesser wing, which here forms the projection known as the **anterior clinoid process** (processus clinoideus anterior), which overhangs the fore part of the body of the bone. The anterior root, broad and compressed, unites the upper surface of the lesser wing with the fore and upper part of the body. Externally the outer angle terminates in a pointed process which reaches the region of the pterion and there articulates with the frontal, and may come in contact with the great wing. The superior aspect is smooth, and forms in part the floor of the anterior cranial fossa. The inferior surface forms part of the posterior portion of the upper wall of the orbit, and also serves to roof in the **sphenoidal fissure** which separates the lesser from the greater wings below. The anterior edge is ragged and irregular, and articulates with the orbital plates of the frontal. The posterior margin, sharp and sickle-shaped, separates the anterior from the middle cranial fossa, and corresponds to the position of the Sylvian fissure on the surface of the cerebrum.

The **greater** or **temporal wings** (alæ magnæ), as seen from above, are of a somewhat crescentic form. If the inner convex edge of the crescent be divided into fifths, the posterior fifth extends backwards and outwards beyond the body of the bone, presenting a free posterior edge, which forms the anterior boundary of the foramen lacerum medium. This border ends behind in the horn of the crescent, from which a pointed process projects downwards, called the **alar** or **sphenoidal spine** (spina angularis), which is wedged into the angle between the petrous and squamous parts of the temporal bone. The inner surface of the posterior border and spine is furrowed for the cartilaginous **Eustachian tube** (sulcus tubæ), whilst on the inner

side of the spine the course of the chorda tympani nerve is indicated by a groove (Lucas). The second fifth of the convex border of the crescent is fused to the side of the body and united below with the root of the pterygoid process. The angle formed by the union of the great wing with the side of the body posteriorly corresponds to the hinder end of the carotid groove, the outer lip of which is formed by a projecting lamina called the **lingula.** The remaining three-fifths of the convex border is divisible into two nearly equal parts; the inner is a free, curved, sharp margin, which forms the inferior margin of the **sphenoidal fissure** (fissura orbitalis superior), the cleft which separates the great wing from the lesser wing, and which establishes a wide channel of communication between the middle cranial fossa and the cavity of the orbit, transmitting the third, fourth, ophthalmic division of the fifth, and the sixth cranial nerves, together with the ophthalmic veins. Wide of the sphenoidal fissure this edge becomes broad and serrated, articulating with the frontal bone internally, and at the part corresponding to the anterior horn of the crescent, by a surface of variable width, it unites with the anterior inferior angle of the parietal bone. The *external border* corresponds to the concave side of the crescent, and is serrated for articulation with the squamous temporal, being thin and bevelled at the expense of its outer surface above and externally, and broad and thick behind as it passes towards the alar spine. The *superior* or *cerebral surface* is concave from behind forwards, and in its fore part from side to side also; it forms a considerable part of the floor of the middle cranial fossa, and bears the impress of the convolutions of the extremity of the temporal lobe of the cerebrum which rests upon it; towards its outer side it is grooved obliquely by an anterior branch of the middle meningeal artery. The following foramina pierce the great wing: close to and in front of the alar spine is the **foramen spinosum** for the transmission of the middle meningeal artery and its companion vein, together with a recurrent branch from the third division of the V. nerve. In front of and internal to this, and close to the posterior free border, is the **foramen ovale,** of large size and elongated form. This gives passage to the motor root and inferior sensory division of the V. nerve, and admits the small meningeal branch of the middle meningeal artery; a small emissary vein from the cavernous sinus usually passes through this foramen and occasionally also the small superficial petrosal nerve. Near the fore part of the root of the great wing, and just below the sphenoidal fissure, is the **foramen rotundum,** of smaller size and circular form. Through this the second division of the V. nerve escapes from the cranium. Occasionally there is a small canal—the **foramen of Vesalius**—which pierces the root of the great wing to the inner side of the foramen ovale. This opens below into the scaphoid fossa at the base of the internal pterygoid plate, and transmits a small vein. Occasionally there is a small foramen (canaliculus innominatus) to the inner side of the foramen spinosum for the transmission of the small superficial petrosal nerve.

The *outer surface* of the great wing is divided into three well-marked areas; of these the upper two are separated by an oblique jagged ridge, the **malar crest** (margo zygomaticus), for articulation with the orbital process of the malar bone. The lower part of this ridge may occasionally articulate with the malar process of the superior maxilla. Of these two areas the **orbital** (facies orbitalis) is directed forwards and a little inwards; of quadrilateral shape, it forms the back and outer wall of the orbit; plane and smooth, it is bounded behind by the sharp inferior free margin of the sphenoidal fissure, towards the inner extremity of which a pointed spine for the attachment of the inferior common ligament of origin of the ocular muscles can usually be seen. It is limited superiorly by the edge of a rough triangular area which articulates with the frontal bone; anteriorly by the malar crest; whilst inferiorly a free, well-defined horizontal margin constitutes the posterior and external boundary of the spheno-maxillary fissure (fissura orbitalis inferior), which separates this part of the bone from the orbital plate of the superior maxilla. Below this border there is a grooved surface which leads inwards toward the orifice of the foramen rotundum. In the articulated skull this forms part of the posterior wall of the spheno-maxillary fossa.

To the outer side of the malar crest, which bounds it in front, is the **temporal**

area (facies temporalis), concavo-convex from before backwards. It slopes inwards below, where it is separated from the zygomatic area by a well-marked muscular ridge, the **infra-temporal crest** or **pterygoid ridge** (crista infratemporalis). Behind, the temporal surface is bounded by the margin of the great wing which articulates with the squamous temporal, and above by the edge which unites it with the anterior inferior angle of the parietal and the frontal bone. The temporal surface enters into the formation of the floor of the fossa of the same name, and affords an extensive attachment to the fibres of origin of the temporal muscle. The **zygomatic surface** (facies infratemporalis), situated below the infra-temporal crest, corresponds to the under surface of the posterior half of the great wing; it extends as far back as the alar spine and posterior border. Opening on it are seen the orifices of the foramen spinosum and ovale. It is slightly concave from side to side, and is confluent internally with the outer surface of the external pterygoid plate. In front it is bounded by a ridge which curves upwards and outwards from the fore part of the external pterygoid plate to join the infratemporal crest. In the articulated skull this ridge forms the posterior boundary of the pterygo-maxillary fissure. The zygomatic surface overhangs the zygomatic fossa, and affords origin to the upper head of the external pterygoid muscle.

The **pterygoid processes** (processus pterygoidei) spring from the inferior surface of the lateral aspect of the body as well as the under side of the root of the great wings, and pass vertically downwards. Each consists of two laminæ, the external and internal pterygoid plates, fused together anteriorly, and enclosing between them posteriorly the **pterygoid fossa** (fossa pterygoidea). The **external pterygoid plate** (lamina lateralis processus pterygoidei), thin and expanded, is directed obliquely backwards and outwards, its lower part being often somewhat everted. Its hinder edge is sharp, and often has projecting from it one or two spines, to one of which (processus pterygo-spinosus) the pterygo-spinous ligament which stretches towards the alar spine is attached. Externally it furnishes an origin for the lower head of the external pterygoid muscle, and on its inner side, where it forms the lateral wall of the pterygoid fossa, it supplies an attachment for the internal pterygoid muscle.

The **internal pterygoid plate** (lamina medialis processus pterygoidei) is narrower and somewhat stouter. By its inner aspect it forms the posterior part of the lateral wall of the nasal fossæ; externally it is directed towards the pterygoid fossa. Its posterior edge ends below in the hook-like **hamular process** (hamulus pterygoidei), which, reaching a lower level than the external plate, curves backwards and outwards, furnishing a groove in which the tendon of the tensor palati muscle glides; superiorly, the sharp posterior margin of the inner plate bifurcates, so as to enclose the shallow **scaphoid fossa** from which the tensor palati muscle arises, and wherein may occasionally be seen the inferior aperture of the foramen Vesalii. To the inner edge of this fossa, as well as to the posterior border of the internal pterygoid plate, the pharyngeal aponeurosis is attached. Here, too, the cartilage of the Eustachian tube is supported on a slight projection, and the palato-pharyngeus muscle receives an origin, whilst the superior constrictor of the pharynx arises from the lower third of the same border and from the hamular process. Superiorly and internally the inner plate forms an incurved lamina of bone, the **vaginal process** (processus vaginalis), which is applied to the under surface of the lateral aspect of the body reaching inwards, towards the root of the rostrum, from which, however, it is separated by a groove, in which, in the articulated skull, the ala of the vomer is lodged. The angle formed by the vaginal process and the internal edge of the scaphoid fossa forms a projection called the **pterygoid tubercle**, immediately above which is the posterior aperture of the **Vidian canal** (canalis pterygoideus), through which the Vidian nerve and artery are transmitted. On its under surface the vaginal process displays a groove (sulcus pterygo-palatinus) which in the articulated skull is converted into the **pterygo-palatine canal** by its union with the palate bone. In front, at its root, the pterygoid process displays a broad smooth surface (facies spheno-maxillaris), which is confluent above with the root of the great wing around the foramen rotundum, and forms the posterior wall of the spheno-maxillary fossa. Here, to the inner side of the foramen rotundum,

is seen the anterior opening of the **Vidian canal.** Below, the pterygoid plates are separated by an angular cleft, the **pterygoid notch** (fissura pterygoidea); in this is lodged the tuberosity of the palate bone, the margins of which articulate with the serrated edges of the recess.

Connexions.—The sphenoid articulates with the occipital, temporals, parietals, frontal, ethmoid, sphenoidal turbinals, vomer, palate and malar bones, and occasionally with the superior maxillæ.

Architecture.—In the adult the body of the bone is hollow and encloses the sphenoidal air cells, usually two in number, separated by a septum. The arrangement and extent of these air cells vary; sometimes they are multilocular, at other times simple, while occasionally they extend backwards into the basioccipital and outwards and downwards into the roots of the great wings and pterygoid processes. Cases are on record in which in the adult the body of the bone was not pneumatic.

Variations.—Through imperfect ossification the foramen spinosum and foramen ovale are sometimes incomplete posteriorly. On the other hand, owing to the ossification of fibrous bands connecting the several bony points, anomalous foramina are frequently met with. Cases of persistence of the cranio-pharyngeal canal have been recorded.

Ossification.—The sphenoid of man is formed by the fusion of two parts, the **pre-sphenoid** and the **post-sphenoid**, each associated with certain processes. In most mammals the orbito-sphenoids or lesser wings fuse with the pre-sphenoid, whilst the alisphenoids or greater wings, together with the internal pterygoid plate, ankylose with the post-sphenoid. The ossification of these several parts takes place in cartilage, with the exception of the internal pterygoid plate, which is developed from an independent centre in the connective tissue of the lateral wall of the oral cavity (Hertwig).

At the end of the second month a centre appears in the root of the great wing between the foramen ovale and foramen rotundum; from this the ossification spreads outwards and backwards and also downwards into the external pterygoid plate. Meanwhile two centres appear about the same time in the basi-sphenoid in relation to the floor of the sella turcica and on either side of the cranio-pharyngeal canal, around which they ossify, ultimately leading to the obliteration of this channel. Somewhat later a centre appears on either side, from which the lateral aspect of the body and the lingula are developed. Fusion between these four centres is usually complete by the sixth month.

In the pre-sphenoid a pair of lateral nuclei make their appearance about the middle of the third month, just external to the optic foramina; from each of these the orbito-sphenoids (lesser wings) and their roots are developed. About the same time another pair of centres, placed mesial to the optic foramina, constitute the body of the pre-sphenoid. By the coalescence of these in front, and their ultimate union with the basi-sphenoid behind, a cartilaginous interval is enclosed, of triangular shape, which, however, becomes gradually reduced in size by the ingrowth of its margins so as to form two mesially-placed foramina, as may be frequently observed in young bones—one opening on the surface of the olivary eminence, the other being placed anteriorly (Lawrence, "Proc. Soc. Anat." *Journ. Anat. and Physiol.*, vol. xxviii. p. 19).

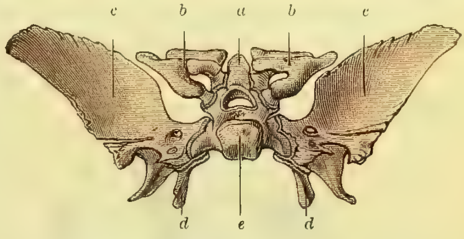


FIG. 94.—OSSIFICATION OF SPHENOID.

a, Presphenoid; *b*, Orbito-sphenoids; *c*, Alisphenoids; *d*, Internal pterygoid plates; *e*, Basisphenoid.

As has been said, the internal pterygoid plates are developed in membrane. Each is derived from a single nucleus which appears about the fourth month and fuses with the under surface of the great wing, there forming a groove, which is converted into the Vidian canal when the alisphenoid and internal pterygoid plates fuse later with the body of the post-sphenoid.

At birth the sphenoid consists of three parts: one comprising the orbito-sphenoids together with the body of the pre-sphenoid and the basi-sphenoid, the others consisting of the alisphenoids, one on either side. Fusion of the latter with the former occurs near the end of the first year. The dorsum sella at birth consists of a cartilaginous plate which separates the body of the post-sphenoid from the basi-occipital. This slowly ossifies, but the cartilage does not entirely disappear till the age of twenty-five, by which time bony ankylosis of the basi-cranial axis is complete. For a considerable time the under surface of the body of the pre-sphenoid displays a bullate appearance, with the sides of which the sphenoidal turbinated bones articulate. It is only after the seventh or eighth year is

reached that the cancellous tissue within this part of the bone becomes absorbed to form the sphenoidal sinuses.

The **sphenoidal turbinals** (conchæ sphenoidales), or bones of Bertin, best studied in childhood, are formed by the fusion of four distinct ossicles (Cleland), the centres for which appear in the later months of utero-gestation. Each bone consist of a hollow three-sided pyramid, the apex of which is in contact with the fore part of the vaginal process of the internal pterygoid, whilst the base fits on to the posterior surface of the lateral mass of the ethmoid. The *inferior surface* of each forms the roof of the corresponding nasal fossa and completes the formation of the spheno-palatine foramen, whilst the external aspect is united with the palate bone and forms the inner wall of the spheno-maxillary fossa and occasionally constitutes a part of the orbital wall posterior to the os planum of the ethmoid. The *superior surface* of the sphenoidal turbinal is applied to the fore and under surface of the body of the pre-sphenoid on either side of the rostrum. It is by the absorption of this wall that the sphenoidal sinuses are ultimately opened up. The base of the pyramid forms the aperture through which each of these sinuses opens into the nasal fossæ in the adult. Owing to their firm ankylosis with the surrounding bones, these ossicles are merely represented in the adult disarticulated skull by the irregular fragments adherent to the separated borders of the ethmoid, palate, and sphenoid bones.

The Ethmoid Bone.

The **ethmoid bone** (os ethmoidale) lies in front of the sphenoid, and occupies the interval between the orbital plates of the frontal, thus entering into the formation of the anterior cranial fossa as well as the inner walls of the orbits and the roof and inner and outer walls of the nasal fossæ. The bone, which is extremely light, consists of two cellular parts—the **lateral masses,** which are united superiorly to a mesial **vertical plate** by a thin horizontal lamina which, from its perforated condition, is called the **cribriform plate.**

The study of this bone will be much facilitated by cutting through the cribriform plate on one side of the vertical plate, thus removing the lateral mass of one side and exposing more fully the central perpendicular lamina.

The **vertical plate** (lamina perpendicularis), of irregular pentagonal shape, forms the upper part of the nasal septum. Its superior border projects above the level of the cribriform plate so as to form a crest, which is much elevated anteriorly, where it terminates in a bullate process called the **crista galli,** the upper edge of which is sharp and pointed, and affords attachment to the falx cerebri. In front of this process there is a groove which separates the **alar processes** (processus alares) which project from the crista galli on either side. By articulation with the frontal bone this groove is converted into a canal, the **foramen cæcum**; this, however, is not always blind, but frequently transmits a vein to the roof of the nose. The *posterior margin* of the vertical plate is thin, and articulates with the crest of the sphenoid. The *posterior inferior border* in the adult is ankylosed with the vomer; and the *anterior inferior edge,* which is usually thicker than the others, unites with the cartilaginous nasal septum. The *anterior superior border* articulates with the nasal spine of the frontal bone and with the median crest formed by the union of the two nasal bones. The vertical plate, which is usually deflected to one or other side, has generally smooth *surfaces,* except above, where they are channelled by

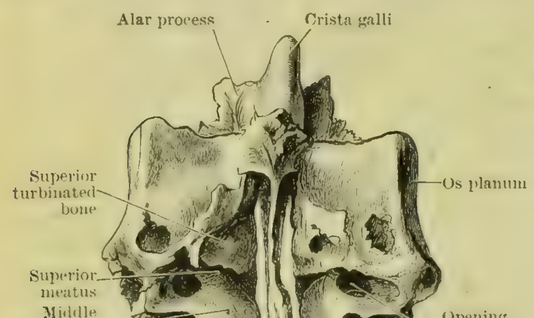


Fig. 95.—Ethmoid as seen from Behind.

short and shallow grooves leading to the foramina which pierce the cribriform plate; these are for the lodgment of the olfactory nerves.

The **lateral mass** or **labyrinth** (labyrinthus) is composed of papery bone, enclosing a large number of air cells; these are arranged in three groups, an anterior, a middle, and a posterior, the walls of which have been broken in front, above, behind, and below, in the process of disarticulation. Externally they are closed in by a thin oblong lamina, the **orbital plate** or **os planum** (lamina papyracea), which forms a part of the inner wall of the orbit, and articulates *above* with the orbital plate of the frontal, which here roofs in the ethmoidal cells. The line of this suture is pierced by two canals, the **anterior** and **posterior ethmoidal canals**, both of which transmit small ethmoidal vessels, whilst the anterior also gives passage to the nasal nerve. *In front* the os planum articulates with the lachrymal bone; whilst *below*, by its union with the orbital surface of the superior maxillary bone, the air sinuses in both situations are completed. *Posteriorly* the os planum articulates with the sphenoid, and at its posterior inferior angle for a variable distance with the orbital process of the palate bone, both of which serve to close in the air cells. The *mesial aspect* of the **lateral mass** displays the convoluted **turbinated processes**, usually two in number, though occasionally there may be three — rarely more. In cases where there are two **ethmo-turbinals** they are separated posteriorly by a deep groove. A channel is thus formed in the back part of the lateral and upper aspect of the nasal fossæ, called the **superior meatus**, which is roofed in by the superior **turbinated process** (concha superior), whilst its floor is formed by the upper surface of the **middle turbinated process** (concha media). The posterior ethmoidal cells open into this meatus. In front of the superior meatus, which only grooves the posterior half of this aspect of the bone, the surface is rounded from above downwards and before backwards, and forms the inner wall of the anterior and middle ethmoidal cells. Running obliquely from above downwards, and backwards over the mesial surface of the superior concha, are a number of fine grooves continuous above with the foramina in the cribriform plate; these are fewer and more scattered in front, do not pass on to the middle concha, and are for the olfactory nerves.

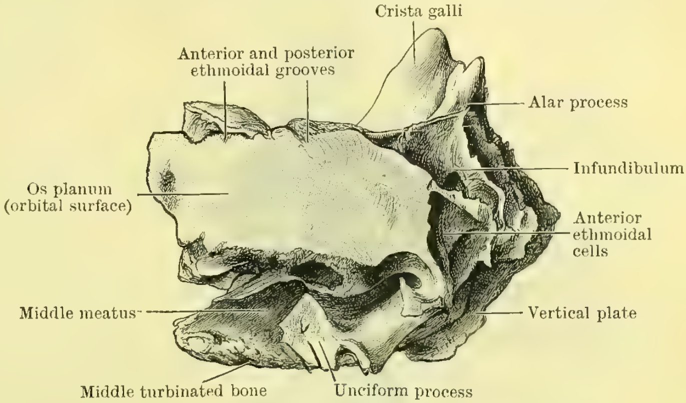


Fig. 96.—Ethmoid as seen from the Right Side.

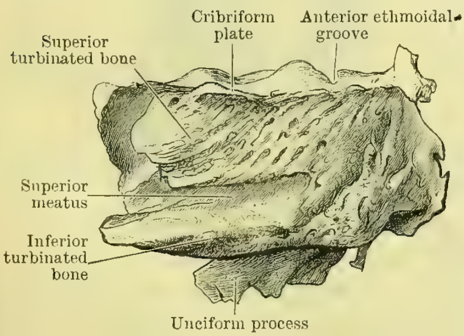


Fig. 97.—Section showing Nasal Aspect of Left Lateral Mass of Ethmoid.

The **middle turbinated process** (concha media) is nearly twice the length of the superior. Its anterior extremity is united for a short distance to the superior turbinated crest on the inner side of the frontal process of the superior maxilla. By its thickened free convoluted border it overhangs a deep groove which runs along the under surface of the lateral mass. This is the **middle meatus of the nose.** It receives the openings of the middle ethmoidal cells and a passage which runs upwards and forwards from it, the **infundibulum.** This communicates with the anterior ethmoidal cells and the frontal sinus. The outer side of the middle meatus is formed by the thin inner

walls of the ethmoidal cells. Curving downwards, backwards, and a little outwards from the roof of the fore part of this meatus is the **uncinate process** (processus uncinatus). This bridges across the irregular opening on the inner wall of the maxillary sinus, and articulates inferiorly with the ethmoidal process of the inferior turbinated bone. The hinder extremity of the middle turbinated bone articulates with the ethmoidal crest on the vertical plate of palate bone.

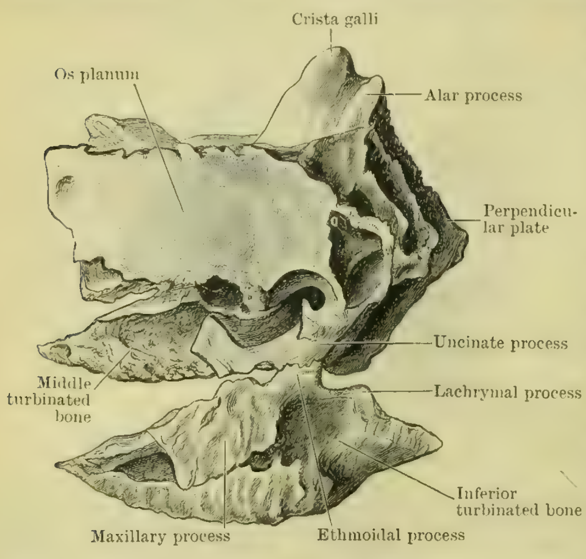


Fig. 98.—Showing Articulation of Inferior Turbinated Bone with Ethmoid.

The **cribriform plate** (lamina cribrosa) is the horizontal lamina which connects the lateral masses with the vertical plate, much in the same manner as the cross limb of a capital T is arranged. It occupies the interval between the orbital plates of the frontal bone, roofing in the nasal fossæ inferiorly, and superiorly forming on either side of the crista galli two shallow **olfactory grooves** in which, in the recent condition, the olfactory lobes of the cerebrum are lodged. Numerous foramina for the transmission of the olfactory nerves pierce this part of the bone—those to the inner and outer sides of the groove are the largest and most regular in their arrangement. Along the outer edges of the cribriform plate two notches can usually be distinguished; when articulated with the frontal bone these form the inner openings of the **ethmoidal canals**. Leading forward from the anterior of these there is often a groove which crosses to the side of the crista galli, where it ends in a slit, which allows of the transmission of the nasal nerve to the nose. Posteriorly the cribriform plate articulates with the ethmoidal spine of the sphenoid.

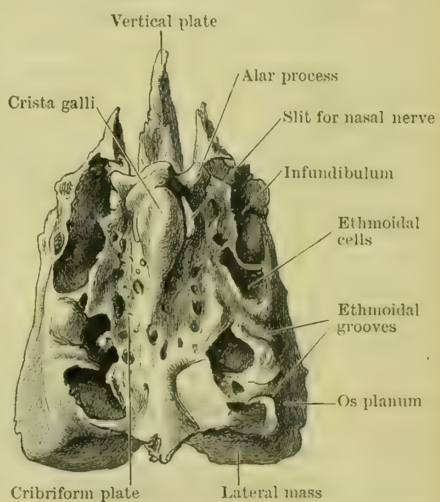


Fig. 99.—Ethmoid as seen from Above.

Connexions.—The ethmoid articulates with the sphenoid and sphenoidal turbinals, the frontal, the two nasals, two superior maxillæ, two lachrymals, two inferior turbinals, two palates, and the vomer.

Variations.—The size of the os planum is liable to considerable variations. In the lower races it tends to be narrower from above downwards than in the higher, in this respect resembling the condition met with in the anthropoids. The os planum may fail to articulate with the lachrymal owing to the union of the frontal with the orbital process of the superior maxilla in front of it. (Orbito-maxillary frontal suture. A. Thomson, *Journ. Anat. and Physiol.*, vol. xxiv. p. 349.) Division of the os planum by a vertical suture into an anterior and posterior part has been frequently recorded. The number of the turbinals may be increased from two to four, or may be reduced to one. (Report of Committee of Collect. Invest. *Journ. Anat. and Physiol.*, vol. xxviii. p. 74.)

Ossification takes place in the cartilage of the nasal capsule. Each lateral mass has one centre, which appears about the fourth or fifth month in the neighbourhood of the os planum. From this the laminæ around the ethmoidal air cells are formed which are complete at birth, the air sinuses in this instance not being formed by the absorption of cancellous bone. From these centres the turbinals are also developed, and these, too, are ossified at the ninth month.

At birth the ossified lateral masses are united to the central cartilaginous plate by a fibrous layer. Two centres make their appearance in the mesial cartilage on either side of the root of the crista galli about the end of the first year; from these, the crista galli and the vertical plate are ossified as well as the mesial part of the cribriform plate, the lateral portions of which are derived from an inward extension of the lateral mass.

Ossification is usually complete about the fifth or sixth year. About the twenty-fifth year bony union has taken place between the cribriform plate and the sphenoid, but ankylosis between the vertical plate and the vomer is not usual till the fortieth or forty-fifth year.

Wormian Bones.

Along the line of the cranial sutures and in the region of the fontanelles, isolated bones of irregular form and variable size are occasionally met with. These are the so-called Wormian bones, named after the Danish anatomist Wormius. They are also called sutural or epactal bones. Their presence depends on the fact that they are either developed from distinct ossific nuclei, or it may be from a division of the primary ossific deposit. They usually include the whole thickness of the cranial wall, or it may be only involve the outer or inner tables of the cranial bones. They are most frequent in the region of the lambda and the lambdoid suture. They occur commonly about the pterion, and in this situation are called epipteric bones (Flower). By their fusion with one or other of the adjacent bones they here lead to the occurrence of a fronto-squamosal suture. Their presence has also been noted along the line of the sagittal suture, and sometimes in metopic skulls in the inter-frontal suture. They are occasionally met with at the asterion and more rarely at the obelion. They appear less frequently in the face, but their presence has been noted around the lachrymal bone, and also at the extremity of the spheno-maxillary fissure, where they may form an independent nodule wedged in between the great wing of the sphenoid, the malar, and the superior maxillary bones.

BONES OF THE FACE.

The bones of the face (ossa faciei), fourteen in number, comprise two superior maxillæ, two palates, two malars, two lachrymals, and two nasals, together with the vomer and inferior maxilla.

The Superior Maxillary Bones.

The **superior maxillæ** (maxillæ), of which there are two, unite to form the upper jaw. Each consists of a **body**, with which are connected four projections, named respectively the **zygomatic, frontal, alveolar,** and **palatal processes.**

The **body** (corpus) is of pyramidal form, and contains within it a hollow called the **antrum** or **maxillary air sinus.** It has four surfaces—an antero-external or facial, a postero-external or zygomatic, a supero-external or orbital, and an internal or nasal. The *antero-external* or **facial surface** (facies anterior) is confluent below with the alveolar process. Above, it is separated from the orbital aspect by the **infraorbital margin** (margo infraorbitalis), whilst internally it is limited by the free margin of the **nasal notch,** which ends below in the pointed **anterior nasal spine** (spina nasalis anterior). Posteriorly it is separated from the zygomatic surface by the inferior border of the **zygomatic process.** The facial aspect of the bone is ridged by the sockets of the teeth (juga alveolaria). The ridge corresponding to the root of the canine tooth is usually the most pronounced; and internal to this, and overlying the roots of the incisor teeth, is the shallow **incisive** or **myrtiform fossa,** whilst placed externally, on a higher level, is the deeper **canine fossa,** the floor of which is formed in part by the projecting zygomatic process. Above this, and near the infraorbital margin, is the **infraorbital foramen,** the external opening of the infraorbital canal, which transmits the infraorbital nerve and artery. The *postero-external* or **zygomatic surface** is separated above from the orbital aspect by a rounded free edge, which forms the anterior margin of the **spheno-maxillary fissure** in the articulated skull. Inferiorly, and in front, it is separated from the facial surface by the zygomatic process and its free lower border. Internally it is limited by a sharp irregular margin with which the palate bone articulates. This surface

is more or less convex and is directed towards the zygomatic and spheno-maxillary fossæ. It is pierced in a downward direction by the apertures of the **posterior dental canals** (foramina alveolaria), two or more in number, which transmit the corresponding nerves and vessels to the molar teeth. Its lower part, slightly more prominent where it overhangs the root of the wisdom molar, is often called the **tuberosity** (tuber maxillare). The *supero-external* or **orbital surface** (planum orbitale), smooth and plane, is triangular in shape and forms part of the floor of the orbit. Its anterior edge corresponds to the infraorbital margin; its posterior border coincides with the anterior boundary of the spheno-maxillary fissure. Its thin inner edge, which may be regarded as the base of the triangle, is notched in front to form the **lachrymal groove** (sulcus lacrimalis), behind which it articulates with the lachrymal bone for a short distance, then for a greater length with the os planum of the ethmoid, and terminates posteriorly in a surface for articulation with the orbital process of the palate bone. Its external angle corresponds to the outspring of the zygomatic process. Traversing its substance is the **infraorbital canal**, the anterior opening of which has been already noticed on the facial aspect of the body. Behind, however, owing to deficiency of its roof, the canal forms a groove which lips the edge of the bone which constitutes the anterior boundary of the spheno-maxillary fissure. If this canal be laid open, the orifices of the middle and anterior dental canals will be seen, which transmit the corresponding vessels and nerves to the bicuspid and incisor teeth. The *inner* or **nasal surface** (facies nasalis) of the body is directed inwards towards the nasal fossæ. Below it is confluent with the upper surface of the palatal process; in front it is limited by the

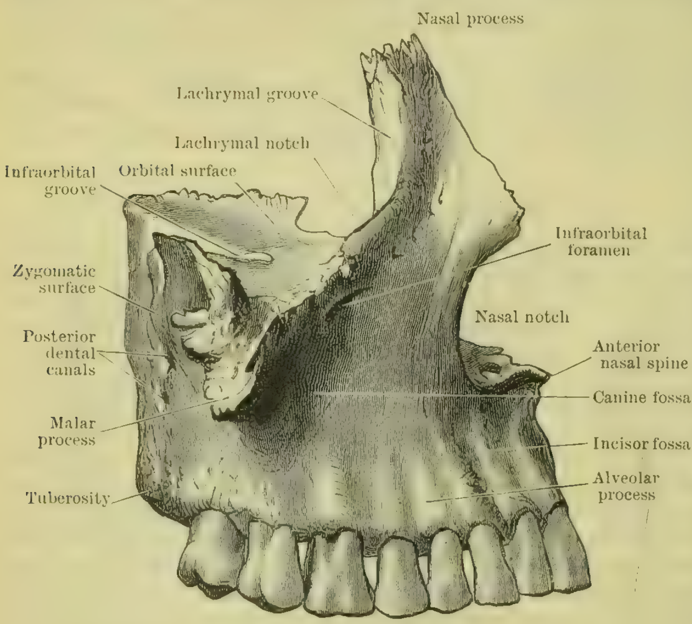


FIG. 100.—RIGHT SUPERIOR MAXILLA (Outer View).

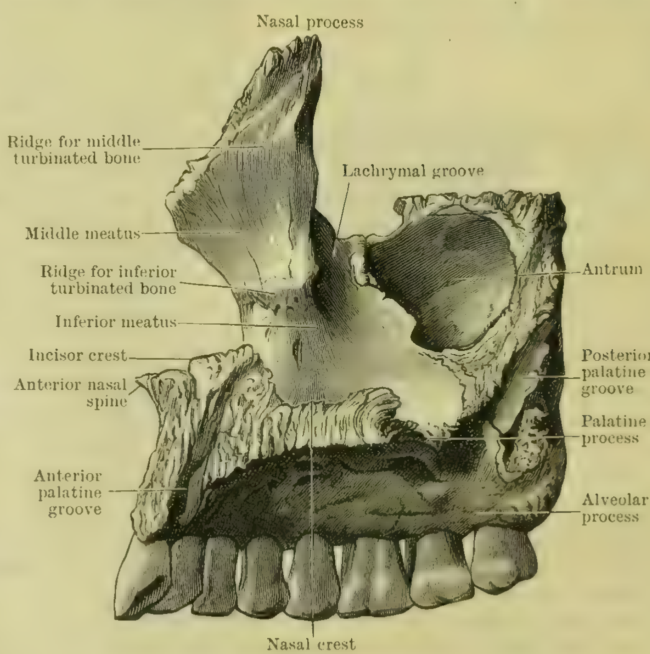


FIG. 101.—RIGHT SUPERIOR MAXILLA (Inner Aspect).

sharp edge of the nasal notch; above and in front it is continuous with the inner surface of the frontal process, behind which it is deeply channelled by the **lachrymal groove,** which is converted into a canal by articulation with the lachrymal and inferior turbinated bones. The channel so formed conveys the nasal duct from the orbital cavity above to the inferior nasal meatus below. Behind this groove the upper edge of this area corresponds to the inner margin of the orbital surface, and articulates from before backwards with the lachrymal, os planum of the ethmoid, and the orbital process of the palate bone. The posterior border, rough for articulation with the palate bone, is traversed obliquely from above downwards and slightly inwards by a groove, which, by articulation with the palate bone, is converted into the **posterior palatine** or **palato-maxillary canal** which transmits the descending palatine artery and great palatine nerve. Towards its upper and hinder part the nasal surface of the body displays the irregular, more or less triangular, opening of the **antrum** (sinus maxillaris). This aperture, which, in the articulated skull opens into the middle meatus of the nose, is much reduced in size by articulation with the ethmoid, palate, and inferior turbinal bones. In front of the lachrymal groove, the inner surface is ridged horizontally by the **inferior turbinated crest** (crista conchalis), to which the inferior turbinated bone is attached. Below this, the bone forms the outer wall of the inferior nasal meatus, receiving the termination of the lachrymal groove. Above, and for some little distance also on the inner side of the frontal process, it constitutes the smooth outer wall of the **atrium** of the middle meatus.

The **zygomatic** or **malar process** (processus zygomaticus), which is placed on the outer surface of the body, is confluent anteriorly with the facial surface of the body; posteriorly, where it is concave from side to side, with the zygomatic surface; whilst superiorly, where it is rough and articular, it forms the apex of the triangular orbital plate, and supports the malar bone. Inferiorly, its anterior and posterior surfaces meet to form an arched border, which fuses with the alveolar process opposite the root of the first molar tooth, and serves to separate the facial from the zygomatic aspects of the body.

The **frontal** or **nasal process** (processus frontalis) rises from the upper and fore part of the body. It has two surfaces—one external, the other internal. The *external* is divided into two by a vertical ridge (crista lachrymalis anterior), which is the upward extension of the infra-orbital margin. The narrow strip of bone behind this ridge is hollowed out, and leads into the lachrymal groove below. Posteriorly the edge of the frontal process here articulates with the lachrymal, and so forms the fossa for the lodgment of the lachrymal sac (fossa sacci lacrimalis). In front of the vertical crest, to which the tendo oculi is attached, the external surface is confluent below with the facial aspect of the body, and forms the side of the root of the nose. Its anterior edge is rough, or grooved, for articulation with the nasal bone. Superiorly the summit of the process is serrated for articulation with the frontal bone. The *inner surface* of the nasal process is directed towards the nasal fossæ. It is crossed obliquely from below upwards and backwards by a ridge—the **agger nasi** or **superior turbinated crest** (crista ethmoidalis). Below this the bone is smooth and forms the upper part of the atrium, whilst the ridge itself articulates posteriorly with the fore part of the middle turbinated process of the ethmoid bone.

The **alveolar process** (processus alveolaris) projects from the under surface of the body of the bone below the level of the palatal process. Of curved form, it completes, with its fellow of the opposite side, the alveolar arch, in which are embedded in sockets or alveoli the roots of the teeth of the upper jaw; ordinarily in the adult, when dentition is complete, each alveolar process supports eight teeth. Piercing the inner surface of the alveolar border behind the incisor teeth two small vascular foramina are usually visible. When any or all the teeth are shed the alveoli become absorbed, and the process may under these circumstances be reduced to the level of the plane of the palatal process. Posteriorly the alveolar process ends below the **tuberosity** of the body; anteriorly it shares in the formation of the **intermaxillary suture.**

The **palatal process** (processus palatinus), of the form of a quadrant, lies in the

horizontal plane; it has two surfaces—upper and under—and three borders, a straight internal, a more or less straight posterior, and a curved external, by which latter it is attached to the inner side of the body and alveolar process as far back as the interval between the second and third molar teeth. Its *under surface*, together with that of its fellow, forms the anterior three-fourths of the vaulted hard palate; it is rough and pitted for the glands of the mucous membrane of the roof of the mouth, and is grooved on either side near the alveolar margin by a channel which passes forward from the **posterior palatine canal** and transmits the great palatine nerve and descending palatine artery. Its *superior surface*, smooth and concave from side to side, forms the floor of the corresponding nasal fossa. Its *internal* or *mesial border*, broad and serrated, rises in a ridge superiorly, so as to form with its fellow of the opposite side the **nasal crest** (crista nasalis), which is grooved superiorly to receive the lower border of the vomer. In front of its articulation with the vomer this ridge rises somewhat higher, being named the **incisor crest**, anterior to which it projects beyond the free border of the nasal notch, and together with its fellow forms the pointed projection called the **anterior nasal spine** (spina nasalis anterior). These parts support the septal cartilage of the nose. Immediately to the outer side of the incisor crest the superior surface of the palatal process is pierced by a foramen which leads downwards, forward, and a little inwards, to open into a broad groove on the mesial border of the bone immediately behind the central incisor tooth. When the two maxillæ are articulated, the two grooves form the oval **anterior palatine canal** or **fossa**, into which the two aforementioned foramina open like the limbs of a Y; these are called the **incisor foramina** or the **foramina of Stenson**, and contain the remains of Jacobson's organs. In front and behind these, and lying within the fossa and in *the line* of the suture, are the smaller **foramina of Scarpa**, which transmit the naso-palatine nerves, the right nerve usually passing through the posterior foramen, the left through the anterior. The *posterior border* of the palatal process, which is sharp and thin, falls in line with the interval between the second and third molar, and articulates with the horizontal plate of the palate bone.

The **maxillary sinus** or **antrum of Highmore** (sinus maxillaris) lies within the body of the bone, and is of corresponding pyramidal form, its base being directed towards the nasal fossa, with the middle meatus of which it communicates, its summit extending outwards into the root of the zygomatic process. It is closed in externally and above by the thin walls which form the facial, zygomatic, and orbital surfaces of the body. Inferiorly it overlies the alveolar process in which the molar teeth are implanted, the sockets of which are separated from it by a thin layer of bone.

Advantage is taken of this circumstance to pierce the floor of the antrum in such conditions as necessitate its thorough drainage, as its natural outlet into the middle meatus is of the nature of an overflow aperture, and so prevents purulent fluids, which may here accumulate, from being readily discharged.

The angles and corners of this cavity are frequently groined by narrow ridges of bone, and the interior is lined by an extension from the mucous membrane of the nose.

Connexions.—The superior maxillary bone articulates with the nasal, frontal, lachrymal, and ethmoid bones above, externally with the malar, and occasionally with the sphenoid, posteriorly and internally with the palate, whilst on its inner side it unites with its fellow of the opposite side, and also supports the inferior turbinated bone and the vomer.

Architecture.—The disposition of the maxillary sinus within the body of the bone has been already referred to. In union with its fellow, the vaulted arrangement of the hard palate is well displayed, and the arched arrangement of the superior alveolar processes is obvious. It is in these latter processes around the sockets for the reception of the teeth that the cancellous tissue of the bone is seen; elsewhere its walls are formed by thin and dense bone.

Variations.—Not unfrequently there is a suture running vertically through the bar of bone which separates the infraorbital foramen from the infraorbital margin. Through imperfections in ossification the infraorbital canal may form an open groove along the floor of the orbit.

Ossification.—The superior maxillæ are developed in the connective tissue around the oral aperture of the embryo. The centres from which the bone ossifies are not preceded by a cartilaginous stage. Their number is uncertain, as early fusion occurs

between them. They first make their appearance in the second month of intrauterine life, shortly after the clavicle has begun to ossify. By the sixth month they are so united that their independent character is obscured. Five centres are described—an *external* or *malar*, which forms the bone to the outer side of the infra-orbital canal; an *inner* or *orbito-nasal*, from which is developed the inner part of the floor of the orbit, the frontal process, and the wall of the antrum; a *palatine*, for the posterior three-fourths of the palatal process; a *nasal*, situated between the frontal process and the canine tooth; and within this and nearer the middle line and below, an *incisive centre*, from which the premaxillæ are developed, thus forming the anterior fourth of the palatal process in the adult. In the early stages of the development of the bone the alveolar groove, in which the teeth are developed, lies close below the infraorbital groove, and it is not till later that they become separated by the growth of the antrum, which first makes its appearance as a shallow fossa to the inner side of the orbito-nasal element about the fourth month. In the adult bone the course of the infraorbital canal and foramen serves to indicate the line of fusion of the orbito-nasal and malar elements, whilst the position of the anterior palatine canal serves to determine the line of union of the incisive with the palatal elements. In addition to the foregoing centres, Rambaud and Renault describe another which, together with its fellow, is wedged in between the incisive and the palatal elements beneath the vomer, thus explaining the Y-shaped arrangement of the foramina of Stenson, which open into the anterior palatine canal.

The **premaxillæ**, which in most vertebrates are independent bones lying in front of the superior maxillæ, constitute in man and apes the portions of the upper jaw which lie in front of the anterior palatine foramen, and support the superior incisor teeth. They are developed from the incisive centres above described; the line of fusion of these elements with the maxillæ proper can readily be seen in young skulls, and occasionally also in the adult. It corresponds to a suture which passes on the palate obliquely outwards and forwards, from the anterior palatine foramen to the interval between the lateral incisor and the canine tooth. In cases of alveolar cleft palate the adjacent bones fail to unite along the line of the suture. In some instances, however, the cleft passes outwards between the central and lateral incisor teeth, and this condition suggests the explanation that the premaxillary element is derived from two centres—a lateral and a mesial. The researches of Albrect and Warinski have confirmed this view. The latter anatomist further observes that the lateral cleavage may lead to a division of the dental germ of the lateral incisor tooth, and so explain the occurrence of the supernumerary incisor which is occasionally met with. In this way the different varieties of cleft palate are readily explained; mesial cleft palate being due to failure of union between the two premaxillary bones. Lateral cleft palate may be of two types: the cleft in one case passing forward between the central and lateral incisor, and being due to the non-union of the two elements from which the premaxilla is primarily developed; the other, in which the cleft passes between the lateral incisor and the canine, or between the lateral incisor and a supernumerary incisor, owing to the imperfect fusion of the premaxilla laterally with the maxilla.

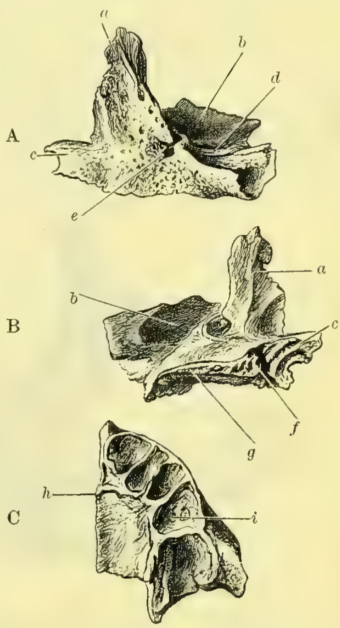


FIG. 102.—OSSIFICATION OF SUPERIOR MAXILLA.

A, Outer side; B, Inner side; C, Under side. *a*, Nasal process; *b*, Orbital plate; *c*, Anterior nasal spine; *d*, Infraorbital groove; *e*, Infraorbital foramen; *f*, Anterior palatine groove; *g*, Palatal process; *h*, Premaxillary suture; *i*, Alveolar process.

THE MALAR BONES.

The **malar bone** (os zygomaticum) underlies the most prominent part of the cheek, and is hence often called the cheek-bone. Placed to the outer side of the orbital cavity, it forms the sharp external border of that hollow, and serves to separate that space from the temporal and zygomatic fossæ which lie behind; below, it rests upon and is united to the superior maxilla; behind, it enters into the formation of the zygomatic arch which bridges across the temporal fossa.

As viewed from the outer side, the bone is convex from side to side and has four angles, of which three are prominent. These are the **ascending** or **frontal** (processus fronto-sphenoidalis), the **anterior** or pointed extremity of the maxillary border, and the **posterior** or **temporal** (processus temporalis).

The most elevated part of the convex *outer surface* (facies anterior) forms the **malar tuberosity.** The **processus temporalis**, sometimes called the zygomatic process, ends posteriorly in an oblique edge, which articulates with the extremity of the zygomatic process of the temporal bone. The **frontal**, the most prominent of its processes, is united superiorly to the external angular process of the frontal bone. The edge between the frontal and temporal processes is thin and sharp; it affords attachment to the temporal fascia, and near its upper end there is usually a pronounced angle (processus marginalis), formed by a sudden change in the direction of the line of the bone. It is just below this point that the temporal branch of the orbital nerve becomes cutaneous. The lower border of the temporal process is somewhat thicker and rounded; it extends downwards and forwards towards the inferior angle, where the bone articulates with the superior maxilla, and is then confluent with the ridge which separates the facial from the zygomatic aspect of

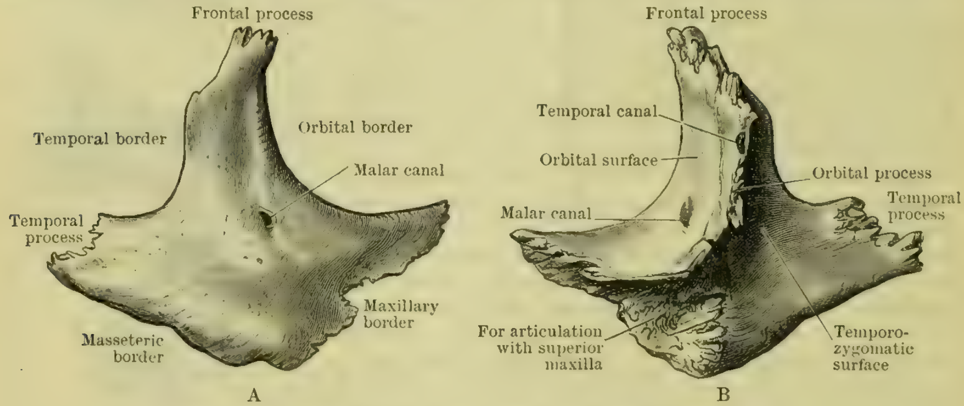


Fig. 103.—Right Malar Bone. A, Outer Side; B, Inner Side.

the upper jaw. This edge of the bone is sometimes called the **masseteric border** since it affords attachment to the fibres of origin of the masseter muscle. Sweeping downwards in front of the frontal process is a curved edge which terminates inferiorly in a pointed process. This border forms the outer and, in part, the inferior margin of the orbital cavity. Between the anterior extremity of the masseteric edge and the pointed anterior angle there is an irregular suture by which the bone is joined to the maxilla. The opening of the **malar canal** (foramen zygomatico-faciale) is seen on the outer surface of the bone; its size and position are very variable.

The *mesial aspect* of the bone is distinguished by a curved elevated crest, called the **orbital process**, which extends inwards and backwards, and is confluent externally with the orbital margin. This process has two surfaces—one anterior, which forms a part of the outer and lower wall of the orbit, and one posterior, which is directed towards the temporal fossa above and the zygomatic fossa below. The free edge of the orbital process is thin and serrated; a little below its middle it is usually interrupted by a non-articular notch, which corresponds to the anterior extremity of the spheno-maxillary fissure. The part above this articulates with the great wing of the sphenoid, the portion below with the orbital plate of the superior maxilla. Behind the orbital process, the inner surface of the bone is concave from side to side, and extends backwards along the mesial aspect of the temporal process and upwards over the posterior half of the inner side of the frontal process, thus entering into the formation of the zygomatic and temporal fossæ respectively. The orbital surface of the orbital process usually displays the openings of two **canals** (foramina zygomatico-orbitalia)—one which traverses the bone below the orbital margin and appears on the front of the bone as already described, the other

which passes obliquely upwards and outwards through the orbital process and appears in the temporal fossa, to the inner side of the frontal process (foramen zygomatico-temporale). The former transmits the ramus subcutaneus malæ; the latter the temporal branch of the orbital nerve.

Below the orbital process there is a rough triangular area, bounded externally by the maxillary border. This articulates with the malar process of the superior maxilla and occasionally forms the outer wall of the antrum.

Connexions.—The malar bone articulates with the frontal, sphenoid, superior maxilla, and temporal bones.

Architecture.—In structure the bone is compact, with little cancellous tissue. Together with the zygomatic process of the temporal bone it forms the buttress which supports the superior maxilla and the outer orbital wall externally. Additional strength is imparted to the bone by the angular mode of union of its orbital and facial parts.

Variations.—Cases of division of the malar bone by a horizontal suture have been recorded, as well as instances of its separation into two parts by a vertical suture. Owing to the supposed more frequent occurrence of this divided condition in Asiatics the malar has been named the os Japonicum. Barclay Smith ("Proc. Anat. Soc." *Journ. Anat. and Physiol.* April 1898, p. 40) describes a case in which the malar bone was divided into two parts, an upper and lower, by a backward extension of the maxilla, which articulated with the zygomatic process of the temporal, thus forming a temporo-maxillary arch. Varieties of a like kind have also been described by Gruber and others. Cases have been noted where, owing to deficiency in the development of the malar, the continuity of the zygomatic arch has been incomplete.

Ossification.—The malar ossifies in membrane most probably from three centres, disposed as follows: one in the posterior part of the bone, the other two in connexion with the orbital process and orbital margin. Appearing as early as the eighth week, these centres are confluent by the beginning of the fifth month of fœtal life.

The Nasal Bones.

The **nasal bones** (ossa nasalia), two in number, lie in the interval between the frontal processes of the superior maxilla, there forming the root or bridge of the nose. Each bone is of elongated quadrangular form, having two surfaces—an inner and outer—and four borders. The *external surface*, somewhat constricted about its middle, is convex from side to side, and slightly concavo-convex from above downwards. Near its centre there is usually the opening of a nutrient canal.

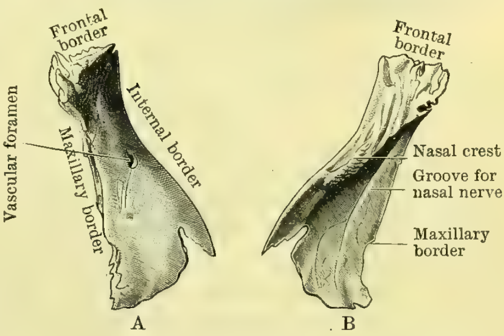


Fig. 104.—Right Nasal Bone. A, Outer side; B, Inner side.

The *internal surface* is not so extensive as the external, as the superior and anterior articular borders encroach somewhat upon it above. Concave from side to side and also from above downwards it is covered, in the recent condition, by the mucous membrane of the nose. Running downwards along this surface is a narrow groove (sulcus ethmoidalis), which transmits the internal nasal nerve. The *anterior* or *internal border*, narrow below, is thick above, and, in conjunction with its fellow at the opposite side, with which it articulates, forms a median crest posteriorly, which is united to the nasal spine of the frontal, the vertical plate of the ethmoid, and the septal cartilage of the nose, in that order from above downwards. The *posterior* or *external border*, usually the longest, is serrated and bevelled to fit on to the anterior edge of the frontal process of the superior maxilla. The *superior border* forms a wide toothed surface, which articulates with the inner part of the nasal notch of the frontal bone anteriorly; whilst, behind, it rests in contact with the root of the nasal process of the same bone. The *inferior border* is thin and sharp, and is connected below with the lateral cartilage of the nose, and is usually deeply notched near its mesial extremity.

Connexions.—The nasal bone articulates with its fellow of the opposite side, with the frontal above, behind with the mesial plate of the ethmoid and with the frontal process of the superior maxilla. It is also united to the septal and upper lateral cartilages of the nose.

Architecture.—Formed of dense and compact bone, the strength of the nasal bones is increased by their mode of union and the formation of a median crest posteriorly.

Variations.—The size and configuration of the nasal bones vary greatly in different races, being, as a rule, large and prominent in the white races, and flat and reduced in size, as well as depressed, in the Mongolian and Negro stock. Obliteration of the internasal suture is unusual; it is stated to occur more frequently in negroes, and is the recognised condition in adult apes.

Ossification.—The nasal bones are each developed from a single centre, which makes its appearance about the end of the second month in the membrane covering the fore part of the cartilaginous nasal capsule. Subsequent to birth the underlying cartilaginous stratum disappears, persisting, however, below in the form of the lateral nasal cartilage, and behind as the septal cartilage of the nose.

The Lachrymal Bones.

The **lachrymal bone** (os lachrymale) or os unguis, a thin scale of bone about the size of a finger-nail, forms part of the inner orbital wall behind the frontal process of the superior maxilla. Irregularly quadrangular, it has two surfaces—an inner and outer—and four borders.

Its *external* or *orbital surface* has a vertical ridge, the **lachrymal crest** (crista lachrymalis posterior), running downwards upon it. In front of this is the **lachrymal groove** (sulcus lachrymalis) for the lodgment of the lachrymal sac. The floor of this groove descends below the level of the bulk of the bone, and forms the **descending process**, which helps to complete the osseous canal for the nasal duct, and articulates inferiorly with the inferior turbinal. The lower end of the lachrymal crest terminates in a hook-like projection, the **hamular process** (hamulus lachrymalis), which curves round the posterior and outer edge of the lachrymal notch of the superior maxilla, and thus defines the upper aperture of the canal for the nasal duct. To the free edge of the crest behind the lachrymal groove are attached the reflected portion of the tendo oculi, and the tensor tarsi muscle. The part of the bone behind the lachrymal crest is smooth and continuous with the surface of the os planum of the ethmoid. The *inner surface* is irregular and cellular above; it closes in some of the anterior ethmoidal cells. Where it is smoother it forms a part of the lateral wall of the middle meatus of the nose immediately behind the frontal process of the superior maxilla, and above the inferior turbinated bone. The *superior border* articulates with the orbital plate of the frontal; the *anterior edge* with the posterior border of the frontal process of the superior maxilla, with which it completes the lachrymal groove for the lodgment of the lachrymal sac. The *inferior margin* articulates with the orbital surface of the superior maxilla, and in front, by its **descending process** with the inferior turbinal. *Posteriorly* the bone articulates with the anterior border of the os planum of the ethmoid.

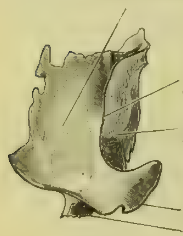


Fig. 105.—Right Lachrymal Bone (Orbital Surface).

Connexions.—The lachrymal bone articulates with four bones—the frontal, ethmoid, inferior turbinal, and the superior maxilla.

Architecture.—The bone consists of a thin papery translucent lamina, somewhat strengthened by the addition of the vertical crest.

Variations.—The lachrymal is occasionally absent. In some cases it is divided into two parts; in others replaced by a number of smaller ossicles. In rare instances the hamular process may extend forwards to reach the orbital margin, and so bear a share in the formation of the face, as in lemurs (Gegenbauer). In other instances the hamulus is much reduced in size. Occasionally the lachrymal is separated from the os planum of the ethmoid by a down-growth from the frontal, which articulates with the orbital process of the superior maxilla, as is the normal disposition in the Gorilla and Chimpanzee. (Turner, *Challenger Reports*, "Zoology," vol. x. Part IV. Plate I.; and A. Thomson, *Journ. Anat. and Physiol.*, London, vol. xxiv. p. 349.)

Ossification.—The lachrymal is developed from a single centre, which makes its appearance about the end of the second or the beginning of the third month of intra-uterine life in the membrane around the cartilaginous nasal capsule.

The Inferior Turbinated Bones.

The **inferior turbinated** or spongy bone (concha inferior) is a shell-like lamina of bone lying along the lower part of the outer wall of the nasal fossa. Of elongated form, the bone displays two curved borders enclosing an internal and external surface.

The *superior* or *attached* border is thin and sharp in front and behind, where it articulates with the inferior turbinal crests on the inner surface of the body of the superior maxilla and the vertical plate of the palate bone, respectively. Between these two borders the central part of the upper edge rises in the form of a sharp crest, the fore part of which forms the upstanding **lachrymal process** (processus lachrymalis), which articulates above with the descending process of the lachrymal bone, as well as with the edges of the nasal groove of the superior maxilla, thus completing the osseous canal of the nasal duct. The posterior end of this crest is elevated in the form of an irregular projection called the **ethmoidal process** (processus ethmoidalis). This unites with the uncinate process of the ethmoid bone (see Fig. 98). Spreading downwards from the middle of the superior border, on its outer side, is a thin irregular plate of bone, the **maxillary process** (processus maxillaris), which partially conceals the outer concave surface

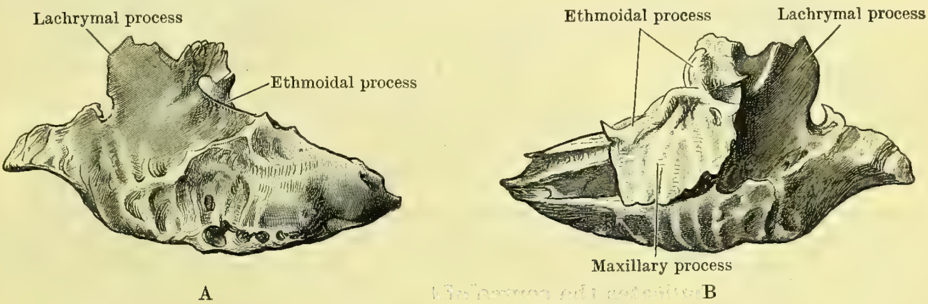


Fig. 106.—Right Inferior Turbinated Bone. A, Inner Surface; B, Outer Surface.

of the bone, and, by its union with the inner wall of the maxillary sinus, assists in the completion of the partition which separates that cavity from the inferior nasal meatus. The *inferior* or *free border*, gently curved from before backwards and slightly out-turned, is rounded and full, and formed of bone which is deeply pitted and of a somewhat cellular character. The anterior and posterior extremities of the bone, formed by the convergence of the upper and lower borders, are thin and sharp; as a rule the hinder end is the more pointed of the two. The *internal surface* projects into the nasal fossa; convex from above downwards, and slightly curved from before backwards, it forms the floor of the middle meatus. It is rough and pitted, and displays some scattered and longitudinally directed vascular grooves. The *outer surface* overhangs the inferior nasal meatus. Concave from above downwards, and to some extent from before backwards, it is directed towards the outer wall of the nasal fossa. It is smooth in front, where it corresponds to the opening of the canal for the nasal duct; behind and towards its lower border, it is irregular and pitted. In the disarticulated bone, this surface is in part concealed by the downward projecting maxillary process.

Connexions.—The inferior turbinal articulates with the superior maxilla, lachrymal, ethmoid, and palate bones.

Variation.—A case in which the inferior turbinals were absent has been recorded by Hyrtl.

Ossification.—The inferior turbinate bone, the maxillo-turbinal of comparative anatomy, is derived from the cartilage forming the outer wall of the nasal capsule, the upper portion of which forms the ethmo-turbinals. It ossifies, however, from a separate centre, which appears about the fifth month of fœtal life, and later contracts a union by a horizontal lamella on its outer side with the superior maxillary bone.

The Vomer.

The **vomer**, a bone of irregular quadrilateral shape, is placed mesially in the hinder part of the nasal septum. It has four borders and two surfaces. The *superior border*, which can readily be distinguished by the presence on either side of an everted lip or ala, slopes from behind upwards and forwards, and articulates with the under surface of the body of the sphenoid, the pointed rostrum of which it receives in the groove formed by the projecting alæ. Laterally these **alæ** are wedged in between the sphenoidal processes of the palate bone in front, and the vaginal processes at the root of the internal pterygoid plates behind. The *posterior border*, which slopes from behind downwards and forwards, is free, and forms a sharp, slightly-curved edge; this constitutes the posterior margin of the nasal septum, and serves to separate the openings of the posterior nares. The *inferior border*, more or less horizontal in direction, articulates with the nasal crest formed by the superior maxillary and palate bones. The *anterior edge* is the longest; it slopes obliquely from above downwards and forwards. In its upper half it is ankylosed to the perpendicular plate of the ethmoid; in its lower half this margin is grooved for the reception of the septal cartilage of the nose. The *anterior extremity* of the bone forms a truncated angle, which articulates with the hinder border of the incisor crest of the superior maxillæ, and sends downwards a pointed process which passes between the incisor foramina. The *right* and *left surfaces* of the bone are smooth, and covered by mucous membrane. It is not uncommon to find them deflected to one or other side. A few vascular grooves may be noticed scattered over these surfaces, and one, usually more distinct than the others, running obliquely downwards and forwards, indicates the course of the nasopalatine nerve.

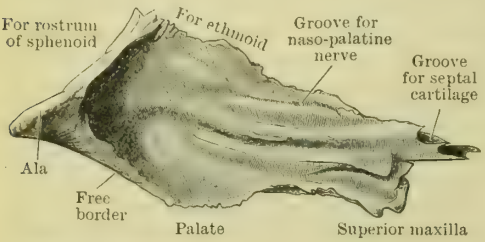


Fig. 107.—Vomer as seen from the Right Side.

Connexions.—The vomer articulates with the sphenoid, the ethmoid, the palates, and the superior maxillæ. In front it supports the septal cartilage.

Architecture.—The bone is composed of two compact layers fused below, but separated above by the groove for the lodgment of the rostrum of the sphenoid behind, and the septal cartilage in front. The lamellæ are also separated from each other by a canal which runs horizontally from behind forwards in the substance of the bone, and which transmits the nutrient vessel of the bone.

Variations.—Owing to imperfect ossification there may be a deficiency in the bone, filled up during life by cartilage. The separation of the two lamellæ along the anterior border varies considerably, and instances are recorded where they were separated by a considerable cavity within the substance of the bone. The spheno-vomerine canal is a minute opening behind the rostrum of the sphenoid, and between it and the alæ of the vomer, by which the nutrient artery enters the bone.

Ossification.—The vomer, primitively double, begins to ossify about the end of the second month of fœtal life. A nucleus appears on either side in the membrane overlying the back and lower part of the vomerine cartilage; these form the primitive lamellæ developed on either side of, and not from, the cartilage. About the third month these laminæ become fused behind and below, thus forming a deep groove in which the cartilage is lodged. As growth goes on the groove becomes reduced by the further fusion of the lateral plates, and the absorption of the cartilage, until the age of puberty, by which time the lateral laminæ have united to form a mesial plate, the primitively divided condition of which is now only represented by the eversion of the alæ, and the grooving along the anterior border.

The Palate Bones.

The **palate bone** (os palatinum), of irregular shape, assists in the formation of the outer wall of the back part of the nasal fossæ, the posterior portion of the hard palate, the orbit, the spheno-maxillary, zygomatic, and the pterygoid fossæ. It

consists of a **horizontal** and a **vertical plate,** united to each other like the limbs of the letter L. At their point of union there is an irregular outstanding process, called the **tuberosity,** whilst capping the summit of the vertical plate and separated by a deep cleft are two irregular pieces of bone, called the **sphenoidal** and **orbital processes.**

The **horizontal plate** (pars horizontalis) has two surfaces and four borders. As its name implies, it is horizontal in position, and forms the posterior third of

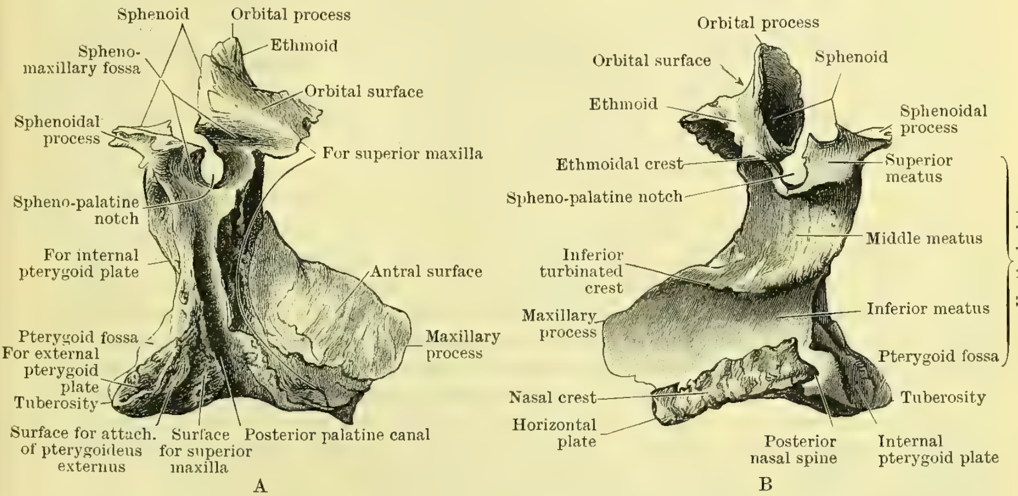


FIG. 108.—RIGHT PALATE BONE.

A, As seen from the Outer Side ; B, As viewed from the Inner Side.

the hard palate. Its *upper surface,* which is smooth, is slightly concave from side to side, and forms the floor of the hinder part of the nasal fossæ. Its *inferior surface,* rougher, is directed towards the mouth, and near its posterior edge often displays a transverse ridge for the attachment of a part of the aponeurosis of the tensor palati muscle. The *anterior border* articulates by means of an irregular suture with the hinder edge of the palatal process of the superior maxilla. The *posterior margin* is free and concave from side to side ; by its sharp edge it furnishes attachment to the aponeurosis of the soft palate. The *internal border* is upturned, and when it articulates with its fellow of the opposite side it forms superiorly a central crest continuous in front with the nasal crest of the superior maxilla; it supports the hinder part of the lower border of the vomer, and projecting beyond the line of the posterior border forms the **posterior nasal** or **palatine spine** (spina nasalis posterior). The *external border* fuses with the vertical plate, forming with it a right angle. The hinder extremity of this edge is grooved by the lower end of the **posterior palatine canal.**

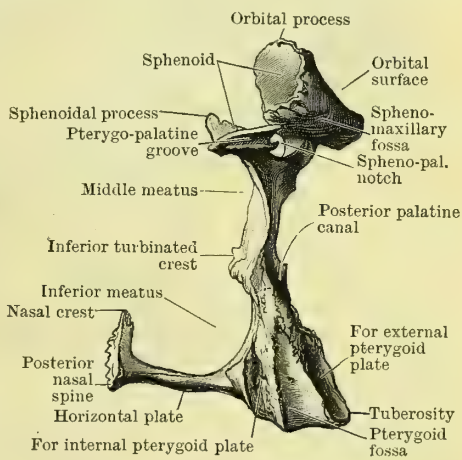


FIG. 109.—RIGHT PALATE BONE.

As seen from Behind.

The **vertical plate** (pars perpendicularis) is very much broader below than above. Composed of thin bone, it is liable to be broken in the process of disarticulation, particularly at its upper part, so that it is somewhat uncommon to meet with a perfect specimen. It may be described as possessing two surfaces and four borders. Its *inner surface,* which is directed towards the cavity of the nose, is crossed horizontally about its middle by the **inferior turbinated crest** (crista

turbinalis), with which the hinder end of the superior border of the inferior turbinated bone articulates; above and below this it enters into the formation of the outer wall of the middle and inferior meatuses of the nose respectively. Near the upper extremity of the vertical plate, and below the processes which spring from it, there is another ridge more or less parallel to that already described. This is the **superior turbinated** or **ethmoidal crest** (crista ethmoidalis), and with this the hinder extremity of the middle turbinated bone is united. The *external surface*, which forms the inner wall of the spheno-maxillary fossa, is channelled by a vertical groove (sulcus pterygo-palatinus), converted into a canal by articulation with the superior maxillary bone. This canal, called the **posterior palatine canal,** transmits the large palatine nerve and descending palatine vessels. Anteriorly the external surface projects forwards to a variable extent, and helps to close in the antrum of the maxilla by its **maxillary process.** The *anterior border* is a thin edge of irregular outline which articulates above with the ethmoid and below with the superior maxilla. The *posterior border*, thin above, where it articulates with the fore part of the internal pterygoid plate, expands below into a pyramidal process called the **tuberosity.** The *inferior border* of the vertical plate is confluent with the outer edge of the horizontal plate; posteriorly, and immediately in front of the tuberosity, it is notched by the lower extremity of the posterior palatine canal. The *superior border* supports the **orbital** and **sphenoidal processes**; the former—the anterior—is separated from the latter by a **notch** (incisura spheno-palatina), which is converted into the **spheno-palatine foramen** by the articulation of the palate bone with the under surface of the sphenoid. Through this communication between the spheno-maxillary and nasal fossæ pass the spheno-palatine artery and the nasal branches of the spheno-palatine ganglion.

The **tuberosity** (processus pyramidalis) is directed backwards and outwards from the angle formed by the vertical and horizontal plates, and presents on its *posterior surface* a central smooth vertical groove, bounded on either side by rough articular furrows which unite above in a V-shaped manner with the upper thin posterior edge. These articulate with the fore parts of the lower portions of the internal and external pterygoid plates, the central groove which fits into the wedge-like interval between the two pterygoid plates thus entering into the formation of the pterygoid fossa. The *outer surface* of the tuberosity is rough above, where it is confluent with the outer surface of the vertical plate which articulates with the tuberosity of the superior maxilla; *below*, there is a small smooth triangular area which appears between the tuberosity of the superior maxilla and the outer surface of the external pterygoid plate, and so enters into the floor of the zygomatic fossa. Passing through the tuberosity in a vertical direction are the **posterior** and **external accessory palatine canals** (foramina palatina minora) for the transmission of the smaller palatine nerves and vessels.

The **orbital process** (processus orbitalis), shaped like a hollow cube, surmounts the fore part of the vertical plate. The open mouth of the cube is directed backwards and inwards towards the fore part of the body of the sphenoid, with the cavity of which it usually communicates; the fore part of the cube articulates with the inner end of the angle formed by the orbital plate and zygomatic surface of the superior maxilla. Of the remaining four surfaces, one directed forwards and inwards articulates with the ethmoid. The others are non-articular: the *superior* enters into the formation of the floor of the orbit; the *external* is directed towards the spheno-maxillary fossa; whilst the *inferior*, which is confluent with the inner surface of the vertical plate, is of variable extent, and overhangs the superior meatus of the nose.

The **sphenoidal process** (processus sphenoidalis), much smaller than the orbital, curves upwards, inwards, and backwards from the hinder part of the summit of the vertical plate. Its superior surface, which is grooved, articulates with the fore part of the under surface of the body of the sphenoid and the root of the internal pterygoid plate, thereby converting the groove into the **pterygo-palatine canal**, which transmits an artery of the same name together with a pharyngeal branch from the spheno-palatine ganglion. Its outer side enters into the formation of part of the inner wall of the spheno-maxillary fossa. Its internal curved aspect is directed

towards the nasal fossa, whilst its inner edge is in contact with the ala of the vomer.

Connexions.—The palate bone articulates with its fellow of the opposite side, with the ethmoid, vomer, sphenoid, superior maxilla, and inferior turbinated bones.

Ossification.—The palate bones are developed from the ossification of the membrane covering the sides of the oral cavity. According to Rambaud and Renault, two primitive centres appear about the sixth week of fœtal life. From one of these the tuberosity and the part of the vertical plate behind the posterior palatine groove is developed ; from the other the remainder of the bone is formed, with the exception of the orbital and sphenoidal processes which are derived from secondary centres that make their appearance somewhat later. Other authorities describe the bone as ossifying from a single centre which appears about the end of the second month in the angle between the vertical and horizontal plates.

At birth the bone is much longer in its antero-posterior diameter than in its vertical height, the converse of its typical adult form.

The Inferior Maxillary Bone.

The **inferior maxilla** (mandibula) or **mandible**, of horse-shoe shape, with the extremities upturned, is the only movable bone of the face. Stout and strong, it supports the teeth of the lower dental arch, and articulates with the base of the cranium, by the joints on either side between its condyles and the glenoid fossæ of the temporal bones. The anterior or horizontal part, which contains the teeth, is called the **body** (corpus); the posterior or vertical portions constitute the **rami** (rami mandibulæ).

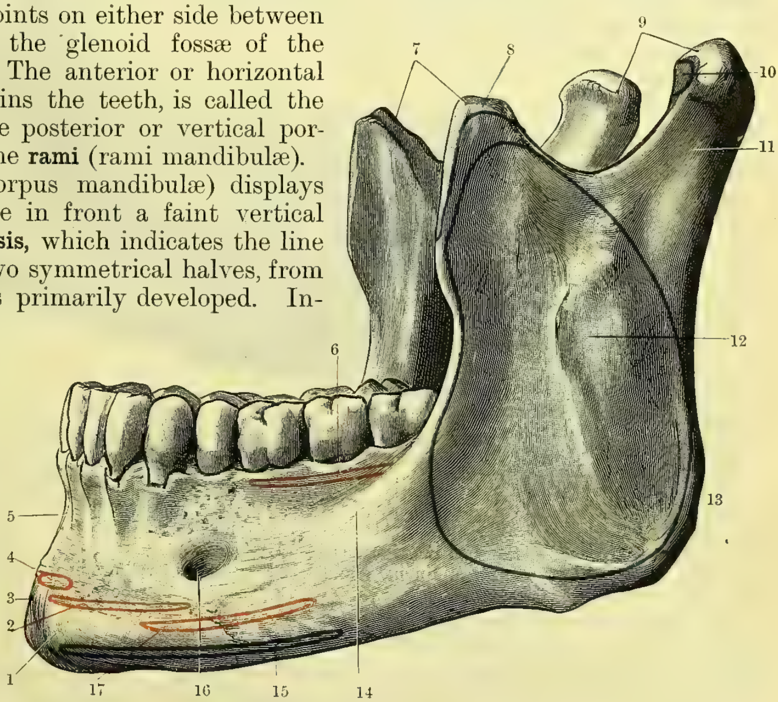


Fig. 110.—The Lower Jaw as seen from the Left Side.

1. Mental tubercle.
2. Depressor labii inferioris.
3. Mental prominence.
4. Levator mentis.
5. Symphysis.
6. Buccinator muscle.
7. Coronoid process.
8. Temporal muscle.
9. Condyles.
10. External pterygoid muscle.
11. Neck.
12. Masseter.
13. Angle.
14. External oblique line.
15. Platysma.
16. Mental foramen.
17. Depressor anguli oris.

The **body** (corpus mandibulæ) displays in the middle line in front a faint vertical ridge, the **symphysis**, which indicates the line of fusion of the two symmetrical halves, from which the bone is primarily developed. Inferiorly this ridge divides so as to enclose, in well-marked specimens, a triangular area—the **mental protuberance** (protuberantia mentalis), the centre of which is somewhat depressed, thus emphasising the inferior angles, which are known as the **mental tubercles** (tubera mentalia). The *outer surface* is crossed by a faint elevated ridge, the **external oblique line** (linea obliqua), which runs upwards and backwards from the mental tubercle to the fore part of the anterior border of the ramus, with which it is confluent. A little above this, midway between the upper and lower borders of the jaw, and in line with the root of the second bicuspid tooth, the bone is pierced by the **mental foramen** (foramen mentale), which is the anterior opening of the inferior dental canal, which traverses the body of the bone. Through this

aperture the mental vessels and nerves reach the surface. The *upper border* supports the sixteen teeth of the lower jaw. It is thick behind and thinner in front, in correspondence with the size of the roots of the teeth. Anteriorly the sockets of the incisor and canine teeth produce a series of vertical elevations (juga alveolaria), of which that corresponding to the canine tooth is the most prominent. When this is outstanding it gives rise to a hollowing of the surface between it and the symphysis, often referred to as the **incisor fossa**; frequently, however, this is only faintly marked. Below the external oblique line the bone is full and rounded, and ends below in the *inferior border* or **base**. This slopes outwards at the sides, and forwards in front, where it is thick and hollowed out on either side of the symphysis to form the **digastric fossæ** (fossæ digastricæ), to which the anterior bellies of the digastric muscles are attached; narrowing somewhat behind this, the inferior border again expands opposite the molar teeth, and finally becoming reduced in width, terminates posteriorly at the **angle** formed between it and the posterior border of the ramus. The *deep* or *inner surface* of the body is crossed by the **internal oblique line** or **mylo-hyoid ridge** (linea mylo-hyoidea). This slants from above downwards and forwards towards the lower part of the symphysis. It serves for the origin of the mylo-hyoid muscle, and also furnishes an attachment to the superior constrictor of the pharynx just behind the last molar tooth. Below the hinder part of this ridge the surface is hollowed to form a **fossa** for the lodgment of the submaxillary gland. Above the fore part of the internal oblique line, the bone is smooth and usually convex.

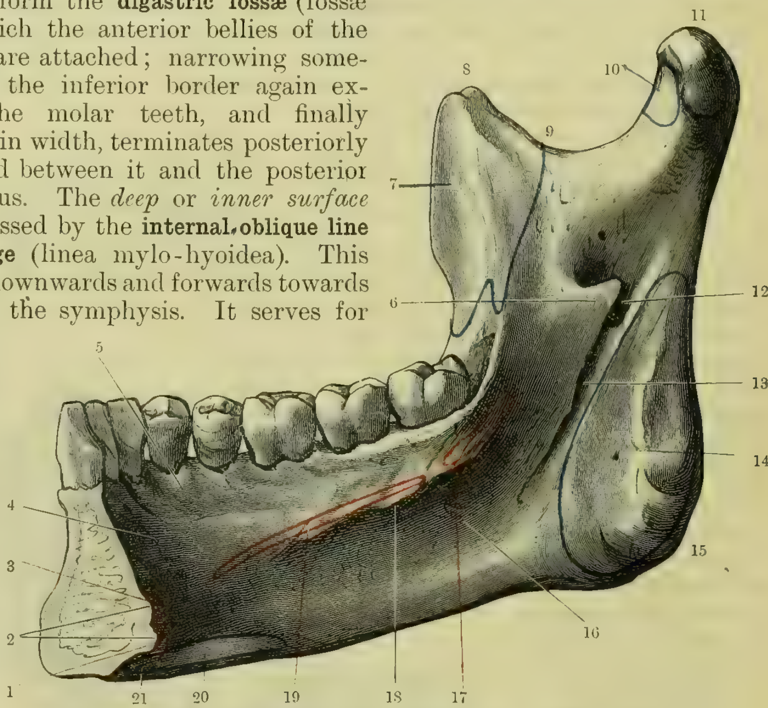


FIG. 111.—THE INNER SIDE OF THE RIGHT HALF OF THE LOWER JAW.

1. Genio-hyoid muscle.
2. Mental spines.
3. Genio-hyoglossus muscle.
4. Surface in relation to the sublingual gland.
5. Alveolar border.
6. Lingula.
7. Temporal muscle.
8. Coronoid process.
9. Sigmoid notch.
10. External pterygoid muscle.
11. Condyles.
12. Inferior dental foramen.
13. Mylo-hyoid groove.
14. Internal pterygoid muscle.
15. Angle.
16. Fossa for submaxillary gland.
17. Superior constrictor.
18. Internal oblique line.
19. Mylo-hyoid muscle.
20. Digastric muscle.
21. Digastric fossa.

Here the sublingual gland lies in relation to it. In the angle formed by the convergence of the two internal oblique lines, and in correspondence with the back of the lower part of the symphysis, there is a raised tubercle surmounted by two laterally placed spines, the **mental** or **genial spines** (spinæ mentales). Occasionally these are again subdivided into an upper and lower pair, or it may be that the lower pair may fuse to form a rough median ridge. To the upper pair of spines the genio-hyoglossi muscles are attached, whilst the lower pair serve for the origin of the genio-hyoid muscles. Immediately above the tubercle there is a median foramen for the transmission of a nutrient vessel, and close to the alveolar border opposite the intervals between the central and lateral incisors, there are two little vascular canals.

The **ramus** (ramus mandibulæ) passes upwards from the back part of the bone, forming by the junction of its posterior border with the base of the body the **angle** (angulus mandibulæ), which is usually rounded and more or less everted. The outer surface of the ramus affords attachment to the masseter muscle, and when

that muscle is powerfully developed the bone is usually marked by a series of oblique curved ridges, best seen towards the angle. About the middle of the deep or inner surface is the large opening (foramen mandibulare) of the **inferior dental canal,** which runs downwards and forwards to reach the body, and transmits the inferior dental vessels and nerves. This aperture is overhung in front by a pointed scale of bone, the **lingula,** to the edges of which the internal lateral ligament of the temporo-maxillary articulation is attached. Behind the lingula and leading downwards and forwards for an inch or so from the opening of the inferior dental canal is the **mylo-hyoid groove** (sulcus mylo-hyoideus), along which the mylo-hyoid artery and nerve pass. Behind and below this groove the inner surface of the angle is rough for the attachment of the internal pterygoid muscle. Superiorly the ramus supports the **coronoid process** in front, and the **condyle** behind, the two being separated by the wide **sigmoid notch** (incisura mandibulæ), over which there pass in the recent condition the vessels and nerve to the masseter muscle. The **coronoid process,** of variable length and beak-shaped, is limited behind by a thin curved margin, which forms the anterior boundary of the sigmoid notch. In front its anterior edge is convex from above downwards and forwards, and becomes confluent below with the anterior border of the ramus and the external oblique line. To the inner side of this ridge there is a grooved elongated triangular surface, the inner margin of which, commencing above near the summit of the coronoid process, leads downwards along the inner side of the root of the last molar tooth towards the internal oblique line. Behind this ridge the thickness of the ramus is much reduced. The temporal muscle is inserted into the margins and inner surface of the coronoid process. The posterior border of the ramus is continued upwards to support the **condyle** (capitulum mandibulæ), below which it is somewhat constricted to form the **neck** (collum mandibulæ), which is compressed from before backwards, and bounds the sigmoid hollow posteriorly. To the inner side of the neck, immediately below the condyle, there is a little depression (fovea pterygoidea) for the insertion of the external pterygoid muscle. The convex surface of the condyle is transversely elongated, and so disposed that its long axis is inclined nearly horizontally from within outwards and a little forwards. The convexity of the condyle is more marked in its antero-posterior than in its transverse diameter.

Architecture.—The mandible is remarkable for the density and thickness of its inner and outer walls. Where these coalesce below at the base of the body, the bone is particularly stout. Superiorly, where they form the walls of the alveoli, they gradually thin, being thicker, however, on the inner than the outer side, except in the region of the last molar tooth where the inner wall is the thinner. The cancellous substance is open-meshed below, finer and more condensed where it surrounds the alveoli. The inferior dental canal is large and has no very definite wall; it is prolonged beyond the mental foramen to reach the incisor teeth. From it numerous channels pass upwards to the sockets of the teeth, and it communicates freely with the surrounding cancellous tissue. Above the canal the substance of the bone is broken up by the alveoli for the reception of the roots of the teeth. In the substance of the condyle the cancellous tissue is more compact, with a general striation vertical to the articular surface.

Variations.—Considerable differences are met with in the height of the coronoid process: usually its summit reaches the same level as the condyle, or slightly above it; occasionally, however, it rises to a much higher level; in other cases it is much reduced. These differences naturally react on the form of the sigmoid notch. The projection of the mental protuberance is also liable to vary. Occasionally the mental foramen is double, and sometimes the mylo-hyoid groove is for a short distance converted into a canal.

Ossification.—The development of the lower jaw is intimately associated with Meckel's cartilage, the cartilaginous bar of the first visceral or mandibular arch. Meckel's cartilages, of which there are two, are connected proximally with the periotic capsule and cranial base. Their distal ends are united in the region of the symphysis. It is in the connective tissue overlying the outer surface of this cartilaginous arch that the bulk of the lower jaw is developed. The cartilage itself is not converted into bone, but undergoes resorption, except its anterior extremity, which is stated to undergo ossification to form the part of the jaw lying between the mental foramen and the symphysis. In a third or fourth month fœtus the cartilage can be traced from the under surface of the fore part of the tympanic ring downwards and forwards to reach the jaw, to which it is attached at the opening of the inferior dental canal; from this it may be traced forwards as a narrow strip applied to the inner surface of the mandible, which it sensibly grooves.

The proximal end of this furrow remains permanently as the mylo-hyoid groove. The part of the cartilage between the tympanic ring and the jaw becomes converted into fibrous tissue, and persists in the adult as the so-called internal lateral ligament of the temporo-maxillary articulation, its proximal end through the Glaserian fissure being continuous with the slender process of the malleus. The part which is applied to the inner surface of the lower jaw disappears. In the tissue overlying the cartilage ossification begins by several centres as early as the sixth or seventh week of fœtal life, in this respect resembling the clavicle, by which it is alone preceded. The dentary or basal centre forms the outer wall and lower border. With this is united the splenial portion, which appears somewhat later, forming the inner table from near the symphysis backwards towards the opening of the inferior dental canal where it terminates in the lingula. By the union of these two parts a groove is formed, which ultimately becomes covered in, and in which the inferior dental nerve and vessels are lodged. As has been already stated, the part of the body between the symphysis and the mental foramen is regarded as directly developed from the fore part of the Meckelian cartilage. As will have been gathered from the above description, the upper part of the ramus and its processes have no connexion with Meckel's cartilage. The condyle and the coronoid process are each developed from a separate centre, preceded by a cartilaginous matrix. These several centres are all united about the fourth month.

At birth the lower jaw consists of two lateral halves united at the symphysis by fibrous tissue; towards the end of the first or during the second year osseous union between the two halves is complete. In infancy the jaw is shallow and the rami proportionately small; further, owing to the obliquity of the ramus the angle is large, averaging about 150°. The mental foramen lies near the lower border of the bone. Coincident with the eruption of the teeth and the use of the jaw in mastication, the rami rapidly increase in size, and the angle becomes more acute. After the completion of the permanent dentition it approaches more nearly a right angle varying from 110° to 120°. The body of the bone is stout and deep, and the mental foramen usually lies midway between the upper and lower borders. As age advances owing to the loss of the teeth and the consequent shrinkage and absorption of the alveolar border of the bone, the body becomes narrow and attenuated, and the mental foramen now lies close to the upper border. At the same time the angle opens out again (130° to 140°), in this respect resembling the infantile condition.

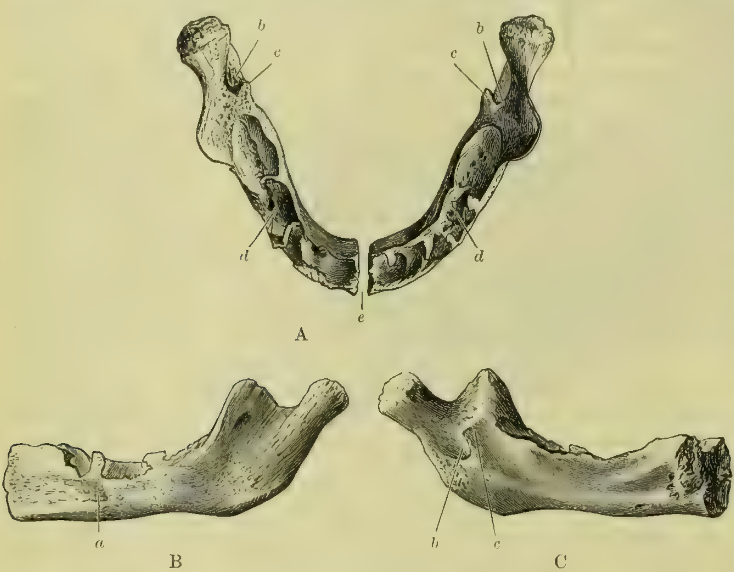


FIG. 112.—LOWER JAW AT BIRTH. A, As seen from above; B, Outer side; C, Inner side.
a, Mental foramen; *b*, Inferior dental canal; *c*, Lingula; *d*, Sockets for the dental sacs.

THE HYOID BONE.

The **hyoid bone** (os hyoideum), or **os linguæ**, though placed in the neck, is developmentally connected with the skull. It lies between the mandible above and the larynx below, and is connected with the root of the tongue. Of U-shaped form, as its name implies (Greek υ and εἶδος, like), it consists in the adult of a central part, or **body**, with which on either side are united two long processes which extend backwards—the **great cornua**. At the point where these are ossified with the body, the **lesser cornua**, which project upwards and backwards, are placed.

The **body** (basis) is arched from side to side and compressed from before backwards, so that its surfaces slope downwards and forwards. Its *anterior surface* displays a slight median ridge, on either side of which the bone is marked by the attachment of muscles. Its *posterior surface*, deeply hollowed, is concave from side to side and from above downwards. Herein lie a quantity of fat and a bursa which separates this aspect from the thyro-hyoid membrane. The upper border is broad; it is separated from the anterior surface by a transverse ridge, behind which are the impressions for the attachment of the genio-hyoid muscles. Its hinder edge is thin and sharp; to this, above, are attached the genio-glossi, whilst behind and below the thyro-hyoid membrane is connected with it. The inferior border is well defined and narrow; it serves for the attachment of the omo-hyoid, sterno-hyoid, and thyro-hyoid muscles.

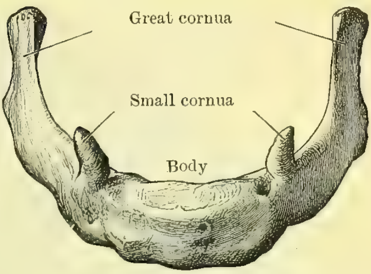


Fig. 113.—The Hyoid Bone as seen from the Front.

The **great cornua** are connected on either side with the lateral parts of the body. At first, union is effected by synchondroses, which, however, ultimately ossify. These cornua curve backwards as well as upwards, and terminate in more or less rounded and expanded extremities. Compressed laterally, they serve for the attachments externally of the thyro-hyoid and hyoglossi muscles, and the middle constrictor of the pharynx from below upwards, whilst internally they are connected with the lateral expansions of the thyro-hyoid membrane, the free edges of which are somewhat thickened, and connect the extremities of the great cornua with the ends of the superior cornua of the thyroid cartilage below.

The **lesser cornua**, frequently cartilaginous in part, are about the size of grains of wheat. They rest upon the upper surface of the bone at the junctions of the great cornua with the body. In youth they are separated from, but in advanced life become ossified with, the rest of the bone, from which they are directed upwards, backwards, and a little outwards. Their summits are connected with the stylo-hyoid ligaments; they also serve for the attachment of muscles.

Connexions.—The hyoid is slung from the styloid processes of the temporal bones by the stylo-hyoid ligaments. Inferiorly it is connected with the thyroid cartilage of the larynx by the thyro-hyoid ligaments and membrane. Posteriorly it is intimately associated with the epiglottis.

Ossification.—In considering the development of the hyoid bone it is necessary to refer to the arrangement and disposition of the cartilaginous bars of the second and third visceral arches. That of the second visceral arch, the hyoid bar—or Reichert's cartilage, as it is sometimes called—is united above to the petrous temporal, whilst ventrally it is joined to its fellow of the opposite side by an independent mesial cartilage. Chondrification of the third visceral arch only occurs towards its ventral extremity, forming what is known as the thyro-hyoid bar. This also unites with the mesial cartilage above mentioned. In these cartilaginous processes ossific centres appear in certain definite situations. Towards the end of fœtal life a single centre (by some authorities regarded as primarily double) appears in the mesial cartilage, and forms the body of the bone (**basihyal**). About the same time ossification begins in the lower ends of the thyro-hyoid bars, and from these the great cornua are developed (thyro-hyals). During the first year the lower ends of the hyoid bars begin to ossify and form the lesser cornua (cerato-hyals). The cephalic ends of the same cartilages meanwhile ossify to form the styloid processes (stylo-hyals), (see p. 117), whilst the intervening portions of cartilage undergo resorption and become converted into the fibrous tissue of the stylo-hyoid ligaments, which in the adult connect the lesser cornua with the styloid processes of the temporal bone. The great cornua fuse with the body in middle life; the lesser cornua only at a more advanced period. Variations in the course of development lead to interesting anomalies of the hyoid apparatus. The lesser cornua may be unduly long or the stylo-hyoid ligament may be bony; in this case the cartilage has not undergone resorption, but has passed on to the further stage of ossification, thus forming an epihyal element comparable to that in the dog. The ossified stylo-hyoid ligament, as felt through the pharyngeal wall, may be mistaken for a foreign body. (Farmer, G. W. S., *Brit. Med. Journ.* 1900, vol. i. p. 1405.)

THE SKULL AS A WHOLE.

The skull as a whole may be studied as seen from the front (norma frontalis), from the side (norma lateralis), from the back (norma occipitalis), from above (norma verticalis), and from below (norma basalis).

Norma Frontalis.

In front, the smooth convexity of the frontal bone limits this region above, whilst inferiorly, when the lower jaw is disarticulated, the teeth of the upper jaw form its lower boundary. The large openings of the **orbits** are seen on either side; whilst placed mesially and at a somewhat lower level, is the **anterior nasal aperture** (apertura pyriforme), leading into the **nasal fossæ.**

The **frontal region,** convex from above downwards and from side to side, is limited externally by two ridges, which are the anterior extremities of the temporal lines. Superiorly the fulness of the bone blends with the convexity of the vertex. Inferiorly the frontal bone forms on either side the arched superior border of the orbit (margo supraorbitalis). The space between these borders corresponds to the root of the nose, and here are seen the sutures which unite the frontal with the nasal bones in the middle line, and with the nasal process of the superior maxilla on either side, called the **naso-frontal** and **fronto-maxillary sutures** respectively. The orbital arch is thin and sharp externally, but becomes thick and more rounded towards its inner side, where it forms the **internal angular process** and unites with the frontal process of the superior maxilla and the lachrymal bone on the inner wall of the orbit. This arched border is interrupted towards its inner side by a notch (incisura supraorbitalis), sometimes converted into a foramen for the transmission of the supraorbital nerve and artery. In the middle line, just above the naso-frontal suture, there is often the remains of a median suture (sutura frontalis), which marks the fusion of the two halves from which the bone is primarily ossified. Here also a prominence, of variable extent—the **glabella**—is met with; from this there passes out on either side above and over the orbital margin a projection called the **superciliary ridge** (arcus superciliaris).

The **orbital fossæ,** of more or less conical form, display a tendency to assume the shape of four-sided pyramids by the flattening of the superior, inferior, and lateral walls. The *base,* which is directed forwards and a little outwards, corresponds to the orbital aperture. The shape of this is liable to individual and racial variations, being nearly circular in the Mongoloid type, whilst it displays a more or less quadrangular form in Australoid skulls. The upper margin, as has been already stated, is formed by the frontal bone between the internal and external angular processes. The outer, and about half the lower, margin are formed by the sharp curved edge between the facial and orbital surfaces of the malar bone. The internal border and the remainder of the lower margin are determined by the outer surface of the frontal process of the superior maxilla, and the sharp edge separating the facial from the orbital surface of the same bone. Three sutures interrupt the continuity of the orbital margin—the **fronto-malar** (sutura zygomatico-frontalis) externally, the **fronto-maxillary** (sutura fronto-maxillaris) internally, both lying about the same level, and the **malo-maxillary** (sutura zygomatico-maxillaris) inferiorly. The *apex* of the space is directed backwards and inwards, so that the inner walls of the two orbits lie nearly parallel to each other, whilst the outer walls are so disposed as to form nearly a right angle with each other. The depth of the orbit measures, on an average, about two inches (5 cm.). At the apex there are two openings; the larger, known as the **sphenoidal fissure** (fissura orbitalis superior), passes from the apex of the space outwards and a little upwards for the distance of three-quarters of an inch or so, between the roof and outer wall of the orbit. The inner third of this fissure is broad and of circular form. Externally it is considerably reduced in width. Through this the third, fourth, ophthalmic division of the fifth, and the sixth nerves enter the orbit, whilst the ophthalmic veins pass backwards through it. Above and internal to the inner end of the sphenoidal

fissure there is a smaller circular opening, the **optic foramen** (foramen opticum), for the transmission of the optic nerve and ophthalmic artery.

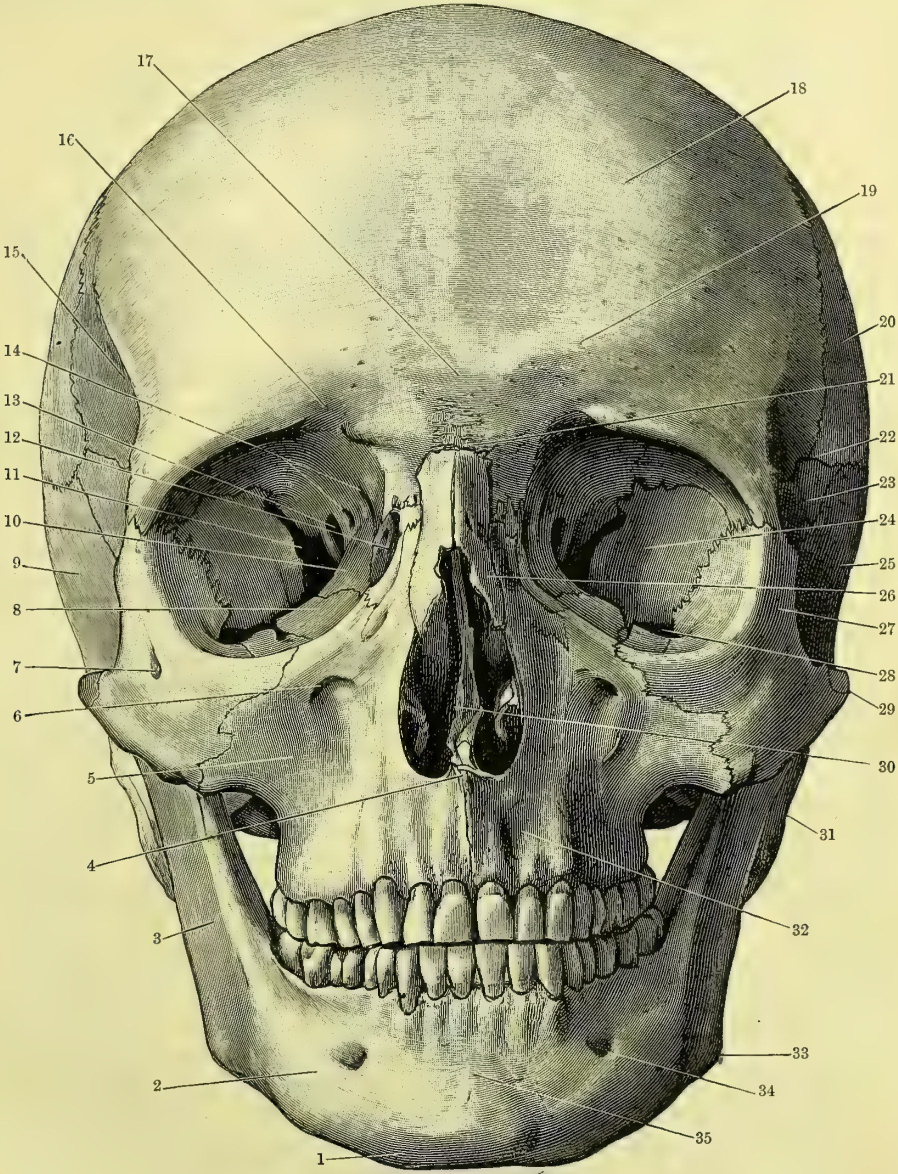


FIG. 114.—NORMA FRONTALIS.

1. Mental protuberance.
2. Body of lower jaw.
3. Ramus of lower jaw.
4. Anterior nasal spine.
5. Canine fossa.
6. Infraorbital canal.
7. Malar canal.
8. Orbital surface of superior maxilla.
9. Temporal fossa.
10. Os planum of ethmoid.
11. Sphenoidal fissure.
12. Lachrymal bone and groove.
13. Optic foramen.
14. Orbital foramina.
15. Temporal ridge.
16. Supraorbital notch.
17. Glabella.
18. Frontal eminence.
19. Superciliary ridge.
20. Parietal bone.
21. Fronto-nasal suture.
22. Pterion.
23. Great wing of sphenoid.
24. Orbital surface of great wing of sphenoid.
25. Squamous temporal.
26. Left nasal bone.
27. Malar bone.
28. Spheno-maxillary fissure.
29. Zygomatic arch.
30. Anterior nasal aperture, displaying nasal septum and inferior and middle turbinated bones.
31. Mastoid process.
32. Incisor fossa.
33. Angle of jaw.
34. Mental foramen.
35. Symphysis.

The *roof of the orbit,* which is very thin and brittle towards its centre, is formed in front by the **orbital plate** of the **frontal bone** (pars orbitalis) and behind by a small triangular piece of the **lesser wing** of the **sphenoid**, which surrounds the

optic foramen and forms the upper border of the sphenoidal fissure. Externally this surface is separated from the outer wall by the sphenoidal fissure posteriorly, anteriorly by an irregular suture between the orbital part of the frontal and the upper margin of the orbital surface of the great wing of the sphenoid, external to which the external angular process of the frontal articulates with the malar. Internally the roof is marked off from the inner wall by a suture, more or less horizontal in direction, between the orbital plate of the frontal and the following bones in order from before backwards, viz. the frontal process of the superior maxilla, the lachrymal bone, and the os planum of ethmoid. In the suture between the last-mentioned bone and the frontal there are two foramina, the **anterior** and **posterior internal orbital** or **ethmoidal canals** (foramen ethmoidale anterius et posterius); both transmit ethmoidal vessels—the anterior affording passage to the nasal nerve as well. The roof is concave from side to side, and to some extent also from before backwards. About midway between the fronto-maxillary suture and the supraorbital notch or foramen, but within the margin of the orbit, there is a small **depression**, occasionally replaced by a spine (fovea vel. spina trochlearis), for the attachment of the cartilaginous pulley of the superior oblique muscle of the eyeball. Under cover of the external angular process the roof is more deeply excavated, forming a shallow **fossa** for the lodgment of the lachrymal gland (fossa glandulæ lachrymalis). In front, the roof separates the orbit from the **frontal sinus**, and along its inner border it is in relation with the **ethmoidal air-cells.** The relation to these air spaces is variable, depending on the development and size of the sinuses. The rest of the roof, which is very thin, forms by its upper surface the floor of the anterior cranial fossa, in which are lodged the frontal lobes of the cerebrum.

The *floor of the orbit* is formed by the **orbital plate** of the **superior maxilla,** together with part of the **orbital surface** of the **malar bone,** and a small triangular piece of bone, the **orbital process** of the **palate**, which is wedged in posteriorly. Externally, for three-quarters of its length posteriorly, it is separated from the outer wall, which is here formed by the great wing of the sphenoid, by a cleft called the **spheno-maxillary fissure** (fissura orbitalis inferior). Through this there pass the superior maxillary division of the fifth nerve on its way to the infraorbital canal, the orbital or temporo-malar branch of the same nerve, the infraorbital vessels, and some twigs from Meckel's (spheno-palatine) ganglion. By means of this fissure the orbit communicates with the spheno-maxillary fossa behind and the zygomatic fossa to the outer side. Internally the floor is limited from behind forwards by the suture between the following bones, viz. the orbital process of the palate below with the body of the sphenoid above and behind, and the os planum of the ethmoid above and in front—anterior to which the orbital plate of the superior maxilla below articulates with the os planum of the ethmoid and the lachrymal above and in front. . At the anterior extremity of this line of sutures the inner edge of the orbital plate of the superior maxilla is notched and free between the point where it articulates with the lachrymal posteriorly and the part from which its frontal process rises. Here it forms the outer edge of a canal, down which the membranous nasal duct passes to the nose. The floor of the orbit is thin behind and at the sides, but thicker in front where it blends with the orbital margin. Passing in a sagittal direction through its substance is the infraorbital canal, the roof of which is usually deficient behind, where it becomes continuous with a broad, shallow groove, which leads forwards from the anterior margin of the spheno-maxillary fissure. This canal (canalis infraorbitalis) opens on the facial surface of the superior maxillary immediately below the orbital margin (foramen infraorbitale) and transmits the superior maxillary division of the fifth nerve, together with the infraorbital vessels. The floor forms a thin partition which separates the orbit from the antrum or sinus of the superior maxilla, which lies below. Internally it completes the lower ethmoidal air-cells, and separates the orbit from the middle meatus of the nasal fossæ.

The *outer wall of the orbit,* which is the strongest, is formed by the orbital surface of the **great wing** of the **sphenoid** and the upper part of the **orbital surface** of the **malar bone.** Above it, behind, is the **sphenoidal fissure**, whilst below, and extending much farther forward, is the **spheno-maxillary fissure.** The anterior

margin of the outer wall is stout and formed by the **malar bone**, behind which, formed in part by the orbital process of the malar bone and the malar edge (margo zygomaticus) of the great wing of the sphenoid, it forms a fairly thick partition between the orbit in front and the temporal fossa behind. Crossing this surface from above downwards close to the anterior extremity of the spheno-maxillary fissure is the suture between the malar bone and the great wing of the sphenoid (sutura spheno-zygomatica). This wall is pierced in front by one or two small canals (foramen zygomatico-orbitale), which traverse the malar bone and allow of the transmission of the temporal and malar branches of the orbital portion of the superior maxillary division of the fifth nerve.

The *inner wall of the orbit* is formed from before backwards by a small part of the **frontal process** of the **superior maxilla**, by the **lachrymal**, and by the **os planum** or orbital plate of the **ethmoid** (lamina papyracea ossis ethmoidalis), posterior to which is a small part of the lateral aspect of the **body** of the **sphenoid** in front of the optic foramen. Above, the orbital plate of the frontal bone forms a continuous suture from before backwards with the bones just enumerated; whilst below, the lachrymal and the orbital plate of the ethmoid articulate with the orbital plate of the superior maxilla; posteriorly the hinder extremity of the os planum and the fore part of the body of the sphenoid articulate with the orbital process of the palate. The orbital surface of the lachrymal bone is divided into two by a vertical ridge—the **lachrymal crest** (crista lachrymalis posterior)—which forms in front the posterior half of a hollow, the **lachrymal groove** (sulcus lachrymalis), the anterior part of which is completed by the channelled posterior border of the **frontal process** of the **superior maxilla**. In the lachrymal groove or fossa (fossa sacci lachrymalis) is lodged the lachrymal sac, whilst passing from it and occupying the canal, of which the upper opening is at present seen, is the membranous nasal duct. The extremely thin wall of the lower part of the lachrymal fossa separates the orbit from the fore part of the middle meatus of the nasal fossa. To the inner side of the upper and fore part of the lachrymal bone, and separated from the orbit merely by the thickness of that bone, is the passage leading from the nose to the frontal sinus (infundibulum ethmoidale), whilst the part of the bone behind the lachrymal crest forms the thin partition between the orbit and the anterior ethmoidal cells. Behind, where the body of the sphenoid forms part of the inner wall of the orbit, the **sphenoidal air sinus** is in relation to the apex of that space, though here the partition wall between the two cavities is much thicker.

The **skeleton of the face** on its *anterior surface* is formed by the two superior maxillæ, the frontal processes of which have been already seen to pass up to articulate with the internal angular processes of the frontal bone, thus forming the lower halves of the inner margins of the orbit. Joined to the upper jaws externally are the **malar** or **cheek bones** (ossa zygomatica), which are supported by their union with the temporal bones posteriorly through the medium of the zygomatic arches. The suture which separates the malar from the superior maxilla (sutura zygomatico-maxillaris) commences above about the centre of the lower orbital margin and passes obliquely downward and outward, its lower end lying in vertical line with the outer orbital margin. The two superior maxillæ are separated by the nasal fossæ, which here open anteriorly. Above, the two nasal bones are wedged in between the frontal processes of the maxillæ; whilst below the nasal aperture, the maxillæ themselves are united in the middle line by the intermaxillary suture (sutura intermaxillaris).

The **nasal aperture** (apertura pyriformis), which lies below and in part between the orbits, is of variable shape and size—usually pyriform, it tends to be long and narrow in Europeans, as contrasted with the shorter and wider form met with in the negroid races. Its edges are formed below and on either side by the free curved margin of the body and the frontal process of the superior maxilla; and above, and partly at the sides, by the free border of the nasal bones. In the middle line, inferiorly, corresponding to the upper end of the intermaxillary suture there is an outstanding process—the **anterior nasal spine** (spina nasalis anterior) formed by the coalescence of spicules from both maxillæ; arising from this, and passing backwards and upwards, is a thin bony partition—the osseous

septum of the nose. Often deflected to one or other side, it divides the cavity of the nose (cavum nasi) into a right and left half. Projecting into these chambers from their outer walls can be seen the inner surfaces and free borders of the **middle** (concha media) and **inferior** (concha inferior) **turbinated bones**, the spaces below and between which form the **inferior** and **middle meatuses** of the nose respectively.

Below the orbit, and to the outer side of the nasal aperture, the anterior or facial surface of the body of the superior maxilla (corpus maxillæ) is seen; this is continuous inferiorly with the outer surface of the alveolar process (process alveolaris), in which are embedded the roots of the upper teeth.

A horizontal line drawn round the jaw on the level of a point midway between the lower border of the nasal aperture and the alveolar edge corresponds to the plane of the **hard palate**. Below that the alveolar process separates the cavity of the mouth from the front of the face; whilst above, the large air space, the **maxillary sinus** (sinus maxillaris), or **antrum of Highmore**, lies within the body of the superior maxilla.

The **malar** or **cheek bone** (os zygomaticum) forms the lower half of the outer, and outer half of the lower border of the orbit. Its outer aspect corresponds to the point of greatest width of the face, the modelling of which depends on the flatness or projection of this bone.

When the **lower jaw** (mandibula) is in position, and the teeth in both jaws are complete, the lower dental arch will be seen to be smaller in all its diameters than the upper, so that when the jaws are closed the upper teeth slightly overlap the lower both in front and at the sides. Exceptionally a departure from this arrangement is met with.

Norma Lateralis.

Viewing this aspect of the skull, in the first instance, without the lower jaw, it is seen to be formed in part by the bones of the cranium, and in part by the bones of the face. A line drawn from the fronto-nasal suture to the tip of the mastoid process serves to define roughly the boundary between these portions of the skull. Of ovoid shape, the cranium is formed above by the **frontal, parietal,** and **occipital bones** from before backwards; whilst below, included within these are the **sphenoid** and **temporal bones.** The sutures between these several bones are arranged as follows:—Commencing at the external angular process of the frontal, the suture between that bone and the malar is first seen; tracing this backwards and a little upwards, the lower edge of the frontal next articulates with the upper margin of the great wing of the sphenoid for a distance varying from three-quarters of an inch to one inch. Here the posterior border of the frontal turns upwards and slightly backwards, forming with the parietal the **coronal suture** (sutura coronalis). The lower border of the parietal bone, which is placed immediately behind the frontal, articulates anteriorly with the hinder part of the upper edge of the great wing of the sphenoid. The extent of this suture (sutura spheno-parietalis) is liable to very great individual variation—at times being broad, in other instances being pointed and narrow, whilst occasionally the parietal does not articulate with the sphenoid at all. Behind the spheno-parietal suture the parietal articulates with the squamous part of the temporal (sutura squamosa). This repeats to a certain extent the curve formed by the outline of the calvaria, and ends posteriorly about one inch behind the **external auditory meatus.** Here the suture alters its character and direction, and in place of being scaly, becomes toothed and irregular, uniting for the space of an inch or so the posterior inferior angle of the parietal with the mastoid process of the temporal bone. This suture (sutura parieto-mastoid) is more or less horizontal in direction, and lies in line and on a level with the upper border of the zygomatic arch. At a point about two inches behind the external auditory meatus the posterior border of the parietal bone turns obliquely upwards and backwards, and forms with the tabular part of the occipital bone the strongly-denticulated **lambdoid suture** (sutura lambdoidea). Inferiorly this suture is continued obliquely downwards between the occipital bone and the hinder border of the mastoid portion of the temporal, where it forms the **occipito-mastoid suture** (sutura occipito-

mastoidea), much simpler and less serrated than the two previously mentioned. These three sutures just described meet in triradiate fashion at a point called the **asterion**.

Anteriorly the curve of the squamous suture is continued downward between the anterior edge of the squamous part of the temporal and the posterior border of

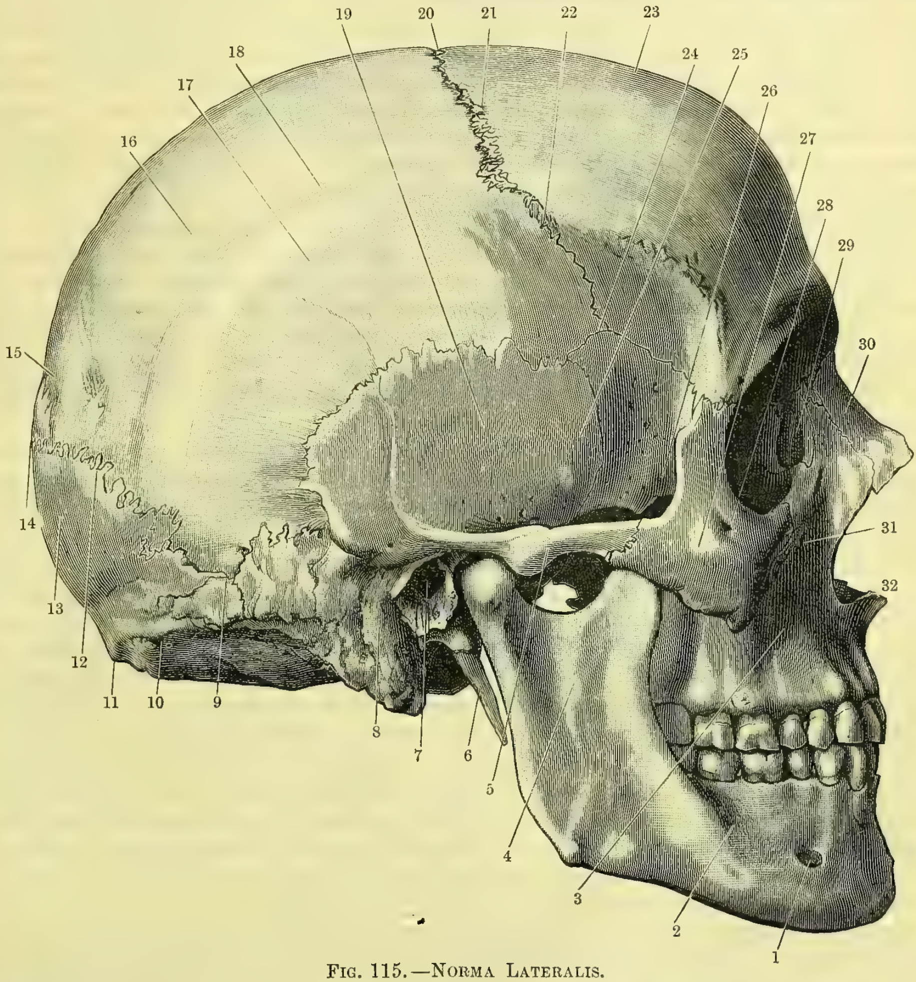


FIG. 115.—NORMA LATERALIS.

1. Mental foramen.
2. Body of lower jaw.
3. Superior maxilla.
4. Ramus of lower jaw.
5. Zygomatic arch.
6. Styloid process.
7. External auditory meatus.
8. Mastoid process.
9. Asterion.
10. Superior curved line of occipital bone.
11. External occipital protuberance.
12. Lambdoid suture.
13. Occipital bone.
14. Lambda.
15. Obelion placed between the two parietal foramina.
16. Parietal bone.
17. Lower temporal ridge.
18. Upper temporal ridge.
19. Squamous part of temporal bone.
20. Bregma.
21. Coronal suture.
22. Stephanion.
23. Frontal bone.
24. Pterion.
25. Temporal fossa.
26. Great wing of sphenoid.
27. Malar bone.
28. Malar canal.
29. Lachrymal bone.
30. Nasal bone.
31. Infraorbital canal.
32. Anterior nasal aperture.

the great wing of the sphenoid; inferiorly it lies in plane with the middle of the zygomatic arch.

The sutures around the summit of the great wing of the sphenoid are arranged like the letter H placed obliquely, the cross piece of the H corresponding to the spheno-parietal suture. When this is short, and becomes a mere point of contact, the arrangement then resembles the letter X. This region is named the **pterion**.

Curving over the lateral region of the calvaria in a longitudinal direction is the **temporal crest** (linea temporalis). This is often double. The lower line marks the limit of the attachment of the temporal muscle, whilst the upper ridge defines

the attachment of the temporal fascia. Commencing in front at the external angular process of the frontal, the crest sweeps upwards and backwards across the lower part of that bone, and then crossing the coronal suture—a point called the **stephanion**—it passes on to the parietal, over which it curves in the direction of its posterior inferior angle. Here it is continued on to the temporal bone, where it sweeps forward to form the **supramastoid crest**, which serves to separate the squamous from the mastoid portion of the temporal bone externally. Carried forward, this ridge is seen to become continuous with the upper border of the zygomatic arch over the external auditory meatus. In front, the temporal ridge separates the temporal fossa from the region of the forehead; above and behind, it bounds the **temporal fossa** which lies within its curve, and serves to separate that hollow from the surface of the calvaria which is overlain by the scalp. Above the level of the temporal lines the surfaces of the frontal and parietal bones are smooth, the latter exhibiting an elevation of varying prominence and position, but usually situated about the centre of the bone, called the **parietal eminence** (tuber parietale). A slight hollowing of the surface of the parietal behind and parallel to the coronal suture is not uncommon, and is referred to as the post-coronal depression. As seen in profile, the part of the calvaria behind and below the lambdoid suture is formed by the tabular part of the occipital bone. In line with the zygomatic arch this outline is interrupted by the **external occipital protuberance** or **inion** (protuberantia occipitalis externa). The projection of this point is variable; but its position can usually be easily determined in the living. Passing forwards from it, and blending anteriorly with the posterior border of the mastoid process of the temporal bone is a rough crest, the **superior curved line** (linea nuchæ superior), a little above which there is often a much fainter line, the **highest curved line** (linea nuchæ suprema); this affords attachment to the epicranial aponeurosis. These two lines serve to separate the part of the cranium above, which is covered by scalp, from that below which serves for the attachment of the fleshy muscles of the back of the neck, the latter surface (planum nuchale) being rough and irregular as contrasted with the smooth superior part (planum occipitale). The fulness of these two parts of the occipital bone varies much. There is frequently a pronounced bulging of the planum occipitale, and the position of the lambda can often be easily determined in the living; similarly the planum nuchale may be either comparatively flat or else full and rounded. These differences are of course associated with corresponding differences in the development of the cerebral and cerebellar lobes which are lodged in relation to the internal aspect of these parts of the bone. The further description of the planum nuchale is best deferred till the base of the skull (norma basalis) is studied.

Temporal Fossa.—Within the limits of the temporal lines the side of the cranium slopes forwards, inwards, and downwards, thus leaving a considerable interval between its lower part and the **zygomatic arch**. This space or hollow is called the temporal fossa (fossa temporalis); bounded above and behind by the temporal lines, its inferior limit is defined by the level of the zygomatic arch. Deepest opposite the angle formed by the frontal and temporal processes of the malar bone, the fossa becomes shallow towards its circumference. Its floor, which is slightly concavo-convex from before backwards about mid-level, is formed above by the temporal surface (facies temporalis) of the frontal, behind by the anterior inferior angle (angulis sphenoidalis) of the parietal, as well as the lower portion of that bone, below the temporal crest; below and in front by the temporal surface of the great wing of the sphenoid, and behind and below by the squamous portion of the temporal bone. Inferiorly the floor is limited in front by the free inferior border of the great wing of the sphenoid, which forms the upper boundary of the **spheno-maxillary fissure**; behind that, by a rough ridge, the **infratemporal crest** or **pterygoid ridge** (crista infratemporalis), which crosses the external surface of the great wing of the sphenoid, to become continuous posteriorly with a ridge on the lower surface of the squamous temporal, from which the anterior root of the zygomatic process springs. In front the temporal fossa is separated from the orbit by the external angular process of the frontal above, and by the orbital process of the malar and its junction with the external border of the great wing of the sphenoid between the orbital and temporal

surfaces of that process. Externally and in front, the fossa is overhung by the backward projection of the frontal process of the malar bone, and it is under cover of this, and within the angle formed by the frontal and orbital processes of the malar, we see the opening of the **temporal canal**, which pierces the orbital plate of the malar and transmits the temporal branch of the orbital nerve—a filament of the superior maxillary division of the V nerve. The fore part of the **spheno-maxillary fissure** (fissura orbita inferior) opens into the lower part of the temporal fossa, and thus establishes a communication between it and the orbit. If the floor of the fossa be carefully examined, some more or less distinct **vascular grooves** may be seen. One passing upwards over the posterior part of the squamous temporal, immediately in front of and above the external auditory meatus, is for the middle temporal artery; two others, usually less distinct, pass up, one over the temporal surface of the great wing of the sphenoid, the other over the fore part of the squamous temporal; these are for the anterior and posterior deep temporal branches of the internal maxillary artery. The fossa contains the temporal muscle with its vessels and nerves, together with the temporal branch of the orbital nerve and some fat; all of which are enclosed by the fascia which stretches over the space from the upper temporal line above to the superior border of the zygomatic arch below. The extent of the fossa depends on the size of the temporal muscle, the development of which is correlated with the size and weight of the lower jaw.

Springing from the front and lower part of the squamous temporal is the **zygomatic process** of that bone; it has two roots, an anterior and a posterior, between and below which are placed the **glenoid fossa** (fossa mandibularis) in front, and the opening of the **external auditory meatus** behind. Of compressed triangular form, the process at first has its surfaces directed upwards and downwards, but curving outwards and forwards, it twists on itself, so that its narrowed surfaces are now turned outwards and inwards, and its edges upwards and downwards; passing forwards, it expands somewhat, and ends in an oblique serrated surface, which unites with the temporal process of the malar bone and completes the **zygomatic arch**. It is the upper edge of this bridge of bone which forms the posterior root. The lower border, turning inwards, forms the anterior root, and serves to separate the temporal from the zygomatic surface of the squamous temporal, blending in front with the **infra-temporal crest** on the outer surface of the great wing of the sphenoid. The under surface of this root is convex from before backwards, and is thrown into relief by the **glenoid hollow**, which passes up behind it. In this way a downward projection, which is called the **eminentia articularis**, is formed.

The **alar spine** of the **sphenoid** (spina angularis) lies immediately to the inner side of the articular part of the glenoid fossa. Its size and projection vary. It is well to remember its relation to the condyle of the lower jaw when that bone is in position; lying, as it does, to the inner side and a little in front of that process, it affords attachment to the so-called long internal lateral ligament (spheno-mandibular) of the temporo-maxillary articulation. As will be seen hereafter, the anterior extremity of the osseous Eustachian canal lies immediately to its inner side (p. 159). A noteworthy feature about the articular part of the glenoid fossa is the thinness of the bony plate which serves to separate it from the middle cranial fossa above. The **vaginal process** is a crest of bone which runs obliquely forwards from the front and inner side of the mastoid process, just below the external auditory meatus, to the alar spine of the sphenoid. Passing downwards and slightly forwards from the centre of this, and ensheathed by it in front and at the sides, is the pointed **styloid process**, the length of which is extremely variable.

In the recess between the posterior root of the zygoma and the upper curved edge of the meatus there is usually a depression, though in some instances this may be replaced by a slight bulging of the bone. If from the posterior root of the zygoma a vertical line be let fall, tangential to the posterior edge of the meatus, a small triangular area is mapped off which has been named by Macewen the **supra-meatal triangle**. Surgically this is of importance, as it is the spot selected in which to trephine the bone to reach the **mastoid antrum** (see p. 116).

In the suture between the posterior border of the mastoid-temporal and the

tabular plate of the occipital, there is usually a **foramen** (**mastoid**) for the transmission of an emissary vein from the lateral sinus within the cranium to the cutaneous occipital vein of the scalp; this opening, which may be double, varies greatly in size, and is usually placed on a level with the external auditory meatus.

Zygomatic Fossa.—The side of the cranium in front of the anterior root of the zygomatic process of the temporal bone is deeply hollowed, forming the **zygomatic** or **infratemporal fossa** (fossa infratemporalis): this in topographical anatomy corresponds to the pterygo-maxillary region. The student must bear in mind that, in examining this space, the ramus and coronoid process of the lower jaw form its outer wall; but this bone for the present being withdrawn, enables us to get a better view of the boundaries of the space. In front its *anterior wall* is formed by the convex posterior or **zygomatic surface** (facies infratemporalis) of the **superior maxilla**, which rises behind the socket for the last molar tooth to form the **tuberosity** (tuber-maxillare). Anteriorly the zygomatic surface of the upper jaw is separated from its facial aspect by the sharp inferior margin of the malar or zygomatic process which supports the malar bone. This latter curves outwards and backwards, forming part of the upper and anterior wall of the fossa. On the inner surface of this wall will be seen the suture uniting the malar and superior maxillary bones (sutura zygomatico-maxillaris), which runs obliquely upwards and inwards to reach the external extremity of the spheno-maxillary fissure, the lower border of which forms the superior boundary of the zygomatic surface of the upper jaw. On this aspect of the bone are to be seen the openings of the **posterior dental canals** (foramina alveolaria) two or more in number, which transmit the nerves and vessels to the upper molar teeth. The *inner wall* of the zygomatic fossa is formed by the outer surface of the **external pterygoid plate** (lamina lateralis processus pterygoidei), the width and shape of which varies greatly; its posterior border is thin and sharp, and often furnished with spiny points, to one of which the pterygo-spinous ligament, which stretches from this border to the alar spine of the sphenoid, is attached. It occasionally happens that this ligament becomes ossified. Anteriorly the external pterygoid plate is separated from the superior maxilla above by an interval called the **pterygo-maxillary fissure.** Below this the bones are apparently fused, but a careful inspection of the skull, together with an examination of the disarticulated bones, will enable the student to realise that, wedged in between the two bones at this point, is a part of one of the smaller bones of the face, the **tuberosity** of the **palate bone** (processus pyramidalis ossis palatini).

The lower border of the external pterygoid plate is usually curved and slightly everted. Superiorly, where the external pterygoid plate is generally narrower, it sweeps upwards to become continuous with the broad under surface of the great wing of the sphenoid; this, which overhangs in part the zygomatic fossa superiorly, is limited above by the **infratemporal crest** which separates its zygomatic from its temporal surface. The zygomatic surface of the great wing of the sphenoid is limited in front and below by the edge which forms the upper boundary of the spheno-maxillary fissure, whilst behind it reaches as far back as the inner extremity of the Glaserian fissure, where it terminates in the alar spine. It is from this point that the suture (sutura spheno-squamosa) curves forward and upwards to reach the region of the pterion. The infratemporal or zygomatic surface of the great wing of the sphenoid, and the outer surface of the external pterygoid plate, alike afford extensive attachments for the external pterygoid muscle, whilst the former is pierced by minute canals for the transmission of emissary veins. Occasionally a larger vascular foramen is present (foramen Vesalii), through which a vein runs from the cavernous sinus within the cranium to the pterygoid venous plexus situated in the pterygo-maxillary region. Immediately behind the root of the external pterygoid plate there is a large oval hole, the **foramen ovale**, and behind that, and in line with the alar spine, is the smaller **foramen spinosum.** These two foramina cannot usually be seen in a side view of the skull, and are better studied when the base is examined; they are mentioned, however, because they transmit structures which here pass from and enter the cranium, viz. the inferior maxillary division of the fifth nerve, together with its motor root, and

the small meningeal artery through the foramen ovale, and the middle meningeal artery and its companion veins through the foramen spinosum. A part of the squamous temporal also forms a small portion of the roof of this fossa; it consists of a triangular area immediately in front of the eminentia articularis, and between it and the anterior root of the zygomatic process of the temporal, which is here curving inwards and forwards, to become continuous with the infratemporal crest. Internally this surface is continuous with the zygomatic surface of the great wing of the sphenoid, separated from it, however, by the hinder part of the spheno-squamosal suture.

When the lower jaw is in position, the zygomatic fossa is concealed by the **ramus** of the mandible, the inner surface of which, in its upper half, forms the outer wall of that space. Viewed from the outer side, the ramus of the inferior maxilla displays considerable differences in different skulls. These are mainly due to variations in its width and in the nature of the angle which it forms at its fusion with the body of the bone. A considerable interval separates the posterior border of the ramus from the front of the mastoid process. Within this space may be seen the free inferior edge of the **tympanic plate** (vaginal process), from which, just below the external auditory meatus, the **styloid process** of the temporal bone is observed passing downwards and slightly forwards. The width and height of the **coronoid process** vary much, oftentimes reaching the level of the top of the condyle. Its extremity, when the lower jaw is closed, lies just within the fore part of the zygomatic arch, at other times rising to a much higher level so that its point may be seen above the level of the upper border of the zygomatic arch. The posterior edge of the coronoid process forms the anterior border of the sigmoid notch, and limits in front the interval left between the lower border of the posterior half of the zygomatic arch and the upper hollowed edge of the ramus. On looking into this interval, the floor of the zygomatic fossa may be seen, formed anteriorly by the external pterygoid plate; whilst posteriorly it is possible to pass a probe right across the base of the skull from one sigmoid notch to the other, the shaft of the probe lying immediately behind the pterygoid processes of the sphenoid, and crossing the foramina ovalia, through which the inferior maxillary divisions of the fifth nerves pass.

The **ramus** and **coronoid process** are so placed as to occupy a position intermediate between the zygomatic arch externally and the external pterygoid plate internally; their inner surface, therefore, forms the outer wall of the zygomatic fossa. On a level with the surface of the crowns of the teeth of the lower jaw, and situated about the middle of this aspect of the ramus, is the **inferior dental foramen** (foramen mandibulare), the superior opening of the **inferior dental canal** (canalis mandibulæ), which traverses the body of the bone. Through this foramen there pass the inferior dental branch of the inferior maxillary division of the fifth nerve, together with the inferior dental artery and its companion veins. As will now be seen, when the lower jaw is in position, the zygomatic fossa is closed in externally by the ramus of the mandible. In front there is an interval between the anterior border of the ramus and the zygomatic surface of the superior maxilla, through which pass the buccal branch of the fifth nerve and the communicating vein between the pterygoid plexus and the facial vein. Above, in the interval between the sigmoid edge and the lower border of the zygomatic arch, there pass from the fossa the vessels and nerves which supply the masseter muscle. Between the posterior border of the ramus and the styloid process there enter and leave the large vessels which are found within the space. Superiorly, under cover of the zygomatic arch, the zygomatic fossa communicates with the temporal fossa, whilst inferiorly it is continuous with the inframaxillary region. Internally, on the floor of the fossa there is an Γ-shaped fissure, the horizontal limb of which corresponds to the **spheno-maxillary fissure**, forming a channel of communication between the fossa and the orbit, through which passes the orbital branch of the superior maxillary division of the fifth nerve; whilst the vertical cleft is the **pterygo-maxillary fissure**, which leads into a small fossa placed between the front of the root of the pterygoid process of the sphenoid and the back of the superior maxilla, called the **spheno-maxillary fossa** (fossa pterygo-palatina).

The following foramina open into the zygomatic fossa—the foramen ovale, foramen spinosum, posterior dental foramina, inferior dental foramen, minute foramina for the transmission of emissary veins; of these one of large size is occasionally present, the foramen of Vesalius.

Spheno-Maxillary Fossa.—This space, which corresponds to the angular interval between the pterygo-maxillary and spheno-maxillary fissures, and which lies between the maxilla in front and the root of the pterygoid process behind, is bounded internally by the vertical plate of the palate bone, which separates it from the nasal cavity, with which, however, it communicates by means of the spheno-palatine foramen, which lies between the orbital and sphenoidal processes of the palate bone and the under surface of the body of the sphenoid. Opening into this fossa, above and behind, are the foramen rotundum, the Vidian canal and the pterygo-palatine canal from without inwards, whilst below is the superior orifice of the posterior palatine canal, together with openings of the accessory posterior palatine canals. Its roof is formed by the under surface of the body of the sphenoid and the orbital plate of the palate bone. Anteriorly it lies in relation to the apex of the orbit, with which it communicates by means of the spheno-maxillary fissure; whilst externally, as already stated, it communicates with the zygomatic fossa through the pterygo-maxillary fissure.

Norma Occipitalis.

This view of the cranium includes the posterior halves of the two parietal bones above, the tabular part of the occipital bone below, and the mastoid portions of the temporal bones on either side inferiorly. The shape of this aspect of the skull varies much, but ordinarily the greatest width corresponds to the level of the parietal eminences. The sutures on this view of the calvaria display a tri-radiate arrangement, one limb of which is vertical, and corresponds to the posterior part of the interparietal or **sagittal suture** (sutura sagittalis). The other two limbs pass outwards and downwards in the direction of the mastoid processes, uniting the two parietal bones in front with the occipital bone behind; these constitute the Λ-shaped **lambdoid suture** (sutura lambdoidea). The point of confluence of the sagittal and lambdoid sutures is called the **lambda.** This can generally be felt in the living, owing to the tendency of the tabular part of the occipital to project slightly immediately below this spot. About one inch and a quarter above the lambda the two small **parietal foramina** (foramina parietalia) are seen, through which pass the small emissary veins of Santorini, which connect the intracranial venous system with the superficial veins of scalp. These small holes lie about $\frac{5}{16}$ of an inch apart on either side of the sagittal suture, which here, for the space of about an inch, displays a simplicity of outline in striking contrast with its serrated arrangement elsewhere. The term **obelion** is applied to a point on the sagittal suture in line with the two parietal foramina. The **lambdoid suture** is characterised by great irregularity of outline, and not unfrequently chains of separated ossicles are met with in it, the so-called **Wormian bones.** The tabular part of the occipital bone is divided into two parts by the **superior curved line** (linea nuchæ superior), the central part of which forms the **external occipital protuberance** (protuberantia occipitalis exterior). The part above, called the occipital surface (planum occipitale), comes within our present consideration; the part below, the nuchal surface (planum nuchale), though seen in perspective, had best be considered when the base is examined. A little above the level of the superior curved line the occipital surface is crossed on either side by a faint lunated line, the **highest curved line** (linea nuchæ suprema) to which are attached the occipitales muscles and the epicranial aponeurosis. The projection of the occipital surface varies much in individual skulls; most frequently it overhangs the external occipital protuberance, forming a distinct boss; exceptionally, however, the latter may be the most projecting part of the bone. The extremity of the superior curved line on either side corresponds to the position of the **asterion** (p. 149). External to these points the outline of the skull is determined by the downward projection of the mastoid processes, the inner surfaces of which are deeply grooved for the attachment of the posterior bellies of

the digastric muscles, thus causing these processes to appear more pointed when viewed from this aspect.

NORMA VERTICALIS.

This is the view of the calvaria as seen from above. It is liable to great diversities of form. Thus its shape may vary from an elongated oval to an outline more nearly circular. These differences have been classified, and form important distinctions from a craniometrical standpoint (p. 173), the rounder varieties being termed the **brachycephalic**, whilst the elongated belong to the **dolichocephalic** group. Another noteworthy point in this view is the fact that in some instances the zygomatic arches are seen, whilst in others they are concealed by the overhang and bulge of the sides of the fore part of the cranium. The former condition is described as **phœnozygous**, the latter as **cryptozygous**, and each is more or less closely associated with the long or round varieties of head-form respectively.

The sutures displayed have a T-shaped arrangement. Placed mesially between the two parietal bones is the **sagittal suture.** This is finely denticulated, except in the region of the obelion, though, of course, this will not be apparent if obliteration of the suture has taken place through fusion of the two parietal bones. Posteriorly the sagittal suture unites with the lambdoid suture at the **lambda**, which marks in the adult the position of the posterior fontanelle of the fœtus. Anteriorly it terminates by joining the transverse suture which separates the frontal bone anteriorly from the parietals behind; this latter is called the **coronal suture**, and the point of junction between the sagittal and coronal suture is known as the **bregma**, which corresponds in position to the anterior fontanelle of the fœtus. The summit of the vault of the calvaria corresponds to a variable point in the line of the sagittal suture, and is named the **vertex.** The **coronal suture** is less denticulated centrally than laterally. Occasionally there is a persistence of the suture which unites the two halves of the frontal bone; under these conditions the line of the sagittal suture is carried forward to the fronto-nasal suture, and a skull displaying this peculiarity is described as **metopic.** Behind the coronal suture may occasionally be seen the **post-coronal depression** (p. 150), and in some instances the vault of the calvaria forms a broad, slightly elevated crest along the line of the sagittal suture. On either side, the temporal ridges can be seen curving over the lateral and superior aspects of the parietal bones. As the lower of these crosses the coronal suture in front it marks a spot known as the **stephanion,** useful as affording a fixed point from which to estimate the bi-stephanic diameter. The interval between the temporal ridges on either side will vary according to the form of the skull and the development of the temporal muscle. In this view of the calvaria a small part of the lambdoid suture on either side of the lambda is visible posteriorly.

NORMA BASALIS.

The base of the cranium—*i.e.* the skull without the mandible—includes a description of the under surfaces of the **skeleton of the face** (cranium viscerale) and the **cranium** (cranium cerebrale). The former includes the **hard palate** formed by the superior maxillæ and palate bones, the **superior dental arch**, and the **bodies of the superior maxillæ** as seen from below; whilst externally, and united with the bodies of the superior maxilla, the **malar** bones are displayed, curving backwards to form the anterior halves of the **zygomatic arches.** In the middle line, passing from the upper surface of the hard palate, is the osseous septum of the nose, here formed by the vomer, which is united above to the under surface of the body of the sphenoid.

The under surface of the cranium is pierced by the **foramen magnum** for the transmission of the spinal cord and its membranes. In front of this a stout bar of bone extends forwards in the middle line, formed by the union of the body of the sphenoid in front with the basilar process of the occipital bone behind. In adult skulls all trace of the fusion of these two bones has disappeared; when union is incomplete, it indicates that the skull is that of a person below the age of twenty-five.

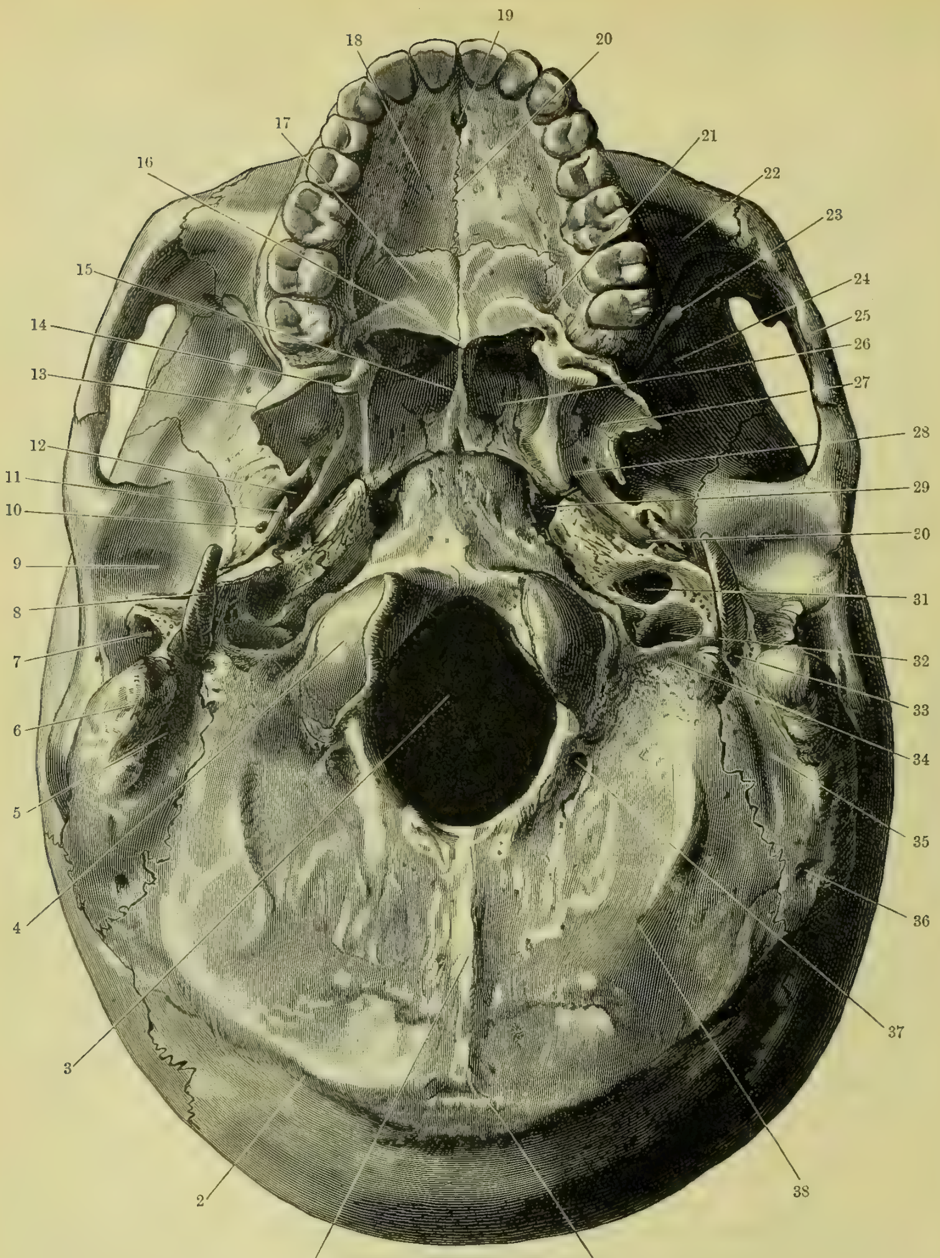


FIG. 116.—NORMA BASALIS.

1. External occipital crest.
2. Superior curved line of the occipital bone.
3. Foramen magnum.
4. Occipital condyle.
5. Digastric groove.
6. Mastoid process.
7. External auditory meatus.
8. Styloid process.
9. Glenoid fossa.
10. Foramen spinosum.
11. Sphenoidal spine.
12. Foramen ovale.
13. External pterygoid plate.
14. Hamular process of internal pterygoid plate.
15. Nasal septum.
16. Posterior nasal spine.
17. Horizontal plate of palate bone.
18. Palatal process of superior maxilla.
19. Anterior palatine canal.
20. Intermaxillary suture.
21. Posterior palatine canal.
22. Malar process of superior maxilla.
23. Spheno-maxillary fissure.
24. Zygomatic fossa.
25. Zygomatic arch.
26. Posterior opening of left nasal fossa.
27. Pterygoid fossa.
28. Scaphoid fossa.
29. Foramen lacerum medium.
30. Opening of osseous Eustachian canal.
31. Carotid canal.
32. Jugular fossa.
33. Stylo-mastoid foramen.
34. Jugular process of occipital bone.
35. Groove for occipital artery.
36. Mastoid foramen.
37. Posterior condylic foramen.
38. Inferior curved line of occipital bone.
39. External occipital protuberance.

The sphenoid comprises that part of the calvaria which forms the roof and sides of the apertures which lie on either side of the nasal septum above the hard palate

—the **choanæ** or **posterior nares.** Laterally the under surfaces of the great sphenoidal wings extend as far forward as the posterior border of the **spheno-maxillary fissure** ; whilst posteriorly they reach as far as the **alar spine**, external to which the spheno-squamosal suture, separating the great wing of the sphenoid from the squamous portion of the temporal, curves forwards and upwards, internal to the eminentia articularis, to reach the floor of the temporal fossa, along which its course has been already traced (p. 150). On a level with the front of the foramen magnum the **jugular process** of the occipital bone forms an irregular curved border, which sweeps outwards to terminate at a point just internal to the root of the styloid process. Here, in line with the spheno-squamosal suture, from which, however, it is separated by a considerable interval, its extremity turns backwards, and may be traced at first internal to, and then turning upwards, behind the mastoid process of the temporal bone, separated from this latter by the occipito-mastoid suture. The bone behind the foramen magnum, which is included between the two occipito-mastoid sutures, comprises the **nuchal surface** of the tabular portion of the occipital bone, an area which is limited behind by the **superior curved line** which separates it from the occipital surface of the same bone. The remaining portions of the base of the calvaria, as at present exposed, are formed by the **squamous** and **tympanic portions** of the **temporal** together with the **petro-mastoid part** of the same bone, the latter of which is wedged in between the great wing of the sphenoid in front and the occipital bone behind. Stretching forwards from the squamous temporal in front is seen the **zygomatic process** which, by its union with the malar, completes the formation of the zygomatic arch.

Studying next the various parts in detail, the **hard palate** (palatum durum) may be first examined. Of horse-shoe shape as a rule, it presents many varieties of outline and size. Formed by the palatal processes (processus palatini) of the superior maxillæ in front and the horizontal plates (partes horizontales) of the palate bones behind, its circumference in front and at the sides corresponds to the **superior alveolar arch**, in which are embedded the sixteen teeth of the upper jaw; posteriorly the edge of the hard palate is thin, ending mesially in a pointed process, the **posterior nasal spine** (spina nasalis posterior), on either side of which the posterior free border is sharp and lunated. The vault of the palate, which is concave from side to side, and from before backwards, varies in depth according to the projection and development of the alveolar processes. When the teeth are shed and the alveoli are absorbed, the palate becomes shallow and flat. Running throughout its entire length in the middle line is the **middle palatine suture** (sutura palatina mediana), which separates the palatal processes of the superior maxillæ in front and the horizontal plates of the palate bones behind. A little behind the central incisor teeth, and in the line of this suture, is a little pit, the **anterior palatine canal** or **fossa** (foramen incisivum). At the bottom of this may be seen the openings of some small canals, varying in number from one to four; these are usually described as arranged in two pairs, the one pair placed side by side, the other lying mesially in front and behind. The former are called the incisor foramina, or foramina of Stenson, and transmit the terminal twigs of the superior or descending palatine arteries which ascend to reach the nasal fossæ. The latter, called the foramina of Scarpa, open, the anterior into the left, the posterior into the right nasal fossa, and afford passage for the fine filaments of the left and right naso-palatine nerves respectively. About half an inch (12 mm.) in front of the posterior nasal spine the middle palatine suture is crossed at right angles by the **transverse palatine suture** (sutura palatina transversa). This, which indicates the line of union of the palatal processes of the superior maxillæ with the horizontal plates of the palate bones, passes transversely outwards on either side until it reaches the inner aspect of the base of the alveolar process, along which it turns backward, to disappear within the **posterior palatine canal** (foramen palatinum majus), a hole which lies immediately internal to the root of the wisdom molar. Through this there pass the superior or descending palatine artery and the large descending palatine nerve. Leading from this foramen is a groove which curves forward immediately to the inner side of the alveolar arch; not unfrequently the inner edge of this groove forms a thin and sharp ridge on the surface of the palate. In this

groove are lodged the aforementioned vessels and nerves. The surface of the palate in front of the transverse suture is rough, pitted for the palatine glands, and pierced by numerous small vascular foramina; the part of the palate behind the suture, formed by the under surface of the horizontal plate of the palate bone, is much smoother. From this there rises, just posterior to the orifice of the posterior palatine canal, a thin sharp crest which curves inwards immediately in front of the posterior free edge; to this are attached some of the tendinous fibres of the tensor palati muscle.

Pterygoid Processes.—Buttressed against the hinder extremities of the alveolar arch are the pterygoid processes of the sphenoid. If carefully examined, these will be seen not to lie in actual contact with the maxillæ, but to be separated from them by the triangular wedge-shaped **tuberosities** (proc. pyramidales) of the palate bones. It is these latter which are pierced by the posterior and external **accessory palatine canals** (foramina palatina minora) which lie just behind the posterior palatine canal, and through which pass the lesser palatine nerves. As here displayed, the **pterygoid processes** (processus pterygoidei) of the sphenoid lie on either side of the opening of the posterior nares; each consists of two plates, an internal (lamina medialis) and an external (lamina lateralis); the latter is the broader, and is directed backwards and slightly outwards. Its external surface has been already studied in connexion with the zygomatic fossa (p. 152). Internally it is separated from the inner pterygoid plate by the **pterygoid fossa** (fossa pterygoidea), wherein is lodged a considerable part of the internal pterygoid muscle. The floor of the fossa is formed in greater part by the coalescence of the two pterygoid plates; but at the level of the hard palate the tuberosity of the palate bone appears wedged in between the two plates, and so enters into the formation of the floor of the pterygoid fossa. The internal pterygoid plate separates the nasal from the pterygoid fossa; to the hinder edge of the internal pterygoid plate are attached the pharyngeal aponeurosis, the superior constrictor of the pharynx, and the palato-pharyngeus muscle. Above, the posterior border of this plate is channelled to form the small **scaphoid fossa** (fossa scaphoidea), which curves outwards over the summit of the pterygoid fossa, and furnishes a surface for the origin of the tensor palati muscle. The sharp inner margin of this fossa, continuous below with the posterior border of the internal pterygoid plate, extends upwards, and on either side of the body of the sphenoid forms a blunt pointed process, the **pterygoid tubercle**, which extends backwards towards the apex of the petrous part of the temporal bone. Just external to this, and concealed by it, is the hinder extremity of the **Vidian canal** (canalis Vidianis), through which pass the Vidian vessels and nerve. The inner surface of the internal pterygoid plate is directed towards the nasal fossæ. Superiorly this surface curves inwards to meet the under surface of the body of the sphenoid, forming on either side a lipped edge, the **vaginal process** (processus vaginalis), between which the alæ of the vomer, which here forms the nasal septum, are wedged. Between the two a small interval, however, is occasionally left, which forms on either side the **basi-pharyngeal canal.** A little external to the line of union of the vaginal process with the vomer is the opening of the **pterygo-palatine canal** (canalis pharyngeus). This lies between the under surface of the vaginal process and the sphenoidal process of the palate bone, which here articulates with the inferior surface of the body of the sphenoid. The pharyngeal branch of the spheno-palatine ganglion and the pterygo-palatine artery pass through this canal. Inferiorly the pterygoid processes project below the level of the hard palate. The inner plate ends in a slender recurved process, called the **hamular process** (hamulus pterygoideus), which turns backwards and outwards; this is frequently broken off in skulls which have been roughly handled. It reaches as low as the level of the alveolar margin, and lies just within and behind the posterior extremity of the alveolar process. It can readily be felt in the living by placing the finger against the soft palate behind and just within the gum around the root of the wisdom tooth. On the front of and below this process the tendon of the tensor palati muscle glides in a groove.

The **posterior nares** (choanæ) lie within and between the pterygoid processes. Of a shape much resembling two Gothic windows, their bases or inferior boundaries are formed by the horizontal plates of the palate bone. Externally they are

bounded by the inner surfaces of the internal pterygoid plates, whilst above, the outer side of the arch is formed by the vaginal processes of the same plate; internally they are separated by the thin vertical posterior border of the vomer, whilst above the everted alæ of the same bone form the inner sides of the arch. The plane of these apertures is not vertical but oblique, corresponding usually to a line drawn from the bregma above through the last molar tooth of the upper jaw below. Their size varies considerably, but the height is usually equal to twice the width.

The region of the cranium which lies external to the superior maxilla and external pterygoid plate corresponds to the **zygomatic fossa**, which has been already described as seen from the side (norma lateralis, p. 152). Viewed from below, the zygomatic fossa is bounded in front by the posterior surface of the body of the superior maxilla and the internal surface of the malar bone. The roof, which is traversed by the spheno-squamosal suture, is formed in front by the under surface of the great wing of the sphenoid, and behind by a small triangular surface of the under side of the squamous part of the temporal bone immediately in front of the eminentia articularis.

Circumscribed externally and behind by the anterior root of the zygoma, which curves forward to become continuous in front with the infra-temporal crest crossing the external surface of the great wing of the sphenoid, the roof of the fossa is separated from its anterior wall by the **spheno-maxillary fissure**, which is so inclined that with its fellow of the opposite side it forms an angle of 90°. Superiorly the zygomatic fossa communicates freely with the temporal fossa beneath the zygomatic arch, though the student must bear in mind the fact that when the inferior maxilla is in position the external limits of the space are very much reduced (p. 153).

The under surface of the great wing of the sphenoid is here V-shaped. The angle corresponds to the spine, the outer limb to the spheno-squamosal suture, whilst the inner limb corresponds to a narrow cleft, the fissura spheno-petrosa, which separates it from the petrous portion of the temporal bone to which it is united in the recent condition by a synchondrosis. Along the line of this latter fissure the edges of the adjacent bones (sphenoid and petrous temporal) are bevelled so as to form a groove, which extends from the root of the inner pterygoid plate internally to the inner side of the base of the alar spine externally, where the groove ends by entering an osseous canal. In the groove (sulcus tubæ auditivæ) is lodged the cartilaginous part of the **Eustachian tube,** whilst the osseous canal includes the bony part of the same tube, together with the tensor tympani muscle, which is lodged in a separate compartment immediately above it. The anterior extremity of the cartilaginous part of the Eustachian tube is supported by the posterior edge of the internal pterygoid plate, which is often notched for its reception. Between the root of the external pterygoid plate and the alar spine there are two foramina, which lie immediately in front of the sulcus tubæ auditivæ. Of these, the larger and anterior is the **foramen ovale**, through which pass the motor root and inferior maxillary division of the fifth nerve, together with the small meningeal artery. The smaller, which from its position immediately in front of the alar spine is called the **foramen spinosum**, transmits the middle meningeal artery and sympathetic plexus surrounding that vessel. The lesser superficial petrosal nerve here passes through the base of the skull to join the otic ganglion either through a small foramen (canalis innominatus) placed between the foramen ovale and the foramen spinosum, or through the foramen ovale or through the spheno-petrosal fissure. The position of the suture between the basioccipital and basisphenoid corresponds to a line connecting the tips of the pterygoid tubercles at the root of the internal pterygoid plates.

Occasionally in the centre of this line there is a small pit with a foramen leading from it. This probably represents the lower end of the cranio-pharyngeal canal.

The under surface of the **basioccipital** (pars basilaris) stretches between the body of the sphenoid in front and the anterior margin of the foramen magnum behind; projecting from its centre is a slight elevation, the **pharyngeal tubercle**

(tuberculum pharyngeum), to which the pharyngeal aponeurosis, together with the central part of the anterior occipito-atlantal ligament, is attached. It should be noted, that when the atlas is in position the pharyngeal tubercle lies in line with the tubercle on the anterior arch of that bone. Curving outwards and backwards from the pharyngeal tubercle, on either side, is an irregular ridge (crista muscularis), in front and behind which are attached the rectus capitis anticus major and minor muscles. On either side of the basioccipital, in front, there is an irregular opening of variable size; this is placed between the root of the pterygoid process anteriorly, the apex of the petrous portion of the temporal bone externally, and the outer edge of the basioccipital and basisphenoid internally. It is called the **foramen lacerum medium.** Opening into it in front, just external to the pterygoid tubercle, is the **Vidian canal,** whilst in correspondence with the apex of the petrous temporal the large orifice of the **carotid canal** may be seen entering it behind and from the outer side. In the recent condition the lower part of the foramen lacerum is occupied by fibro-cartilage, over the upper surface of which the internal carotid artery and great superficial petrosal nerve pass to reach their respective foramina, whilst a small meningeal branch of the ascending pharyngeal occasionally enters the cranium through it. Leading outwards from the foramen lacerum in the direction of the alar spine of the sphenoid is the spheno-petrosal fissure, which lies at the bottom of the **sulcus tubæ auditivæ,** and disappears from view within the **bony Eustachian canal.** Passing backwards from the foramen lacerum there is a fissure between the outer side of the basioccipital and the posterior and inner border of the petrous part of the temporal bone. This, which is called the **petro-occipital fissure** (fissura petro-occipitalis) opens posteriorly into the **jugular foramen.** In the recent condition the fissure is filled up with cartilage. The under surface of the petrous bone included between these two fissures is rough and irregular, and affords attachments near its apex to two small muscles, the levator palati and the tensor tympani. Immediately behind the alar spine the petrous temporal is pierced by a circular hole, the inferior opening of the **carotid canal** (canalis caroticus). This passes upwards, and then turns inwards and forwards towards the apex of the bone, where it may again be seen opening into the outer and upper side of the foramen lacerum. Externally the wall of the vertical part of this canal is usually very thin, and separates it from the cavity of the tympanum, as may be seen by holding the skull up to the light and looking into the external auditory meatus (p. 116). The carotid canal transmits the internal carotid artery, together with the sympathetic plexus around it. It is noteworthy that the two carotid canals lie in line with the anterior edges of the two external auditory meatuses.

The **jugular foramen** is an opening of irregular shape and size placed between the petrous temporal in front and the jugular process of the occipital bone behind. The former is excavated into a hollow called the **jugular fossa,** which forms a roof to the upper and outer part of the space, whilst the latter, by a curved edge, either rounded or sharp, constitutes its posterior border. There is often considerable difference in the size of the jugular foramina; that on the right side (with the skull in its normal position) is usually the larger. The foramen is occasionally subdivided into two by spicules of bone which bridge across it. Lodged within the fossa is the sinus of the internal jugular vein, in front of which the inferior petrosal sinus passes down to join the internal jugular vein below the foramen. Effecting an exit between the two veins, in order from before backwards, are the glosso-pharyngeal, pneumogastric, and spinal accessory nerves. Small meningeal branches from the ascending pharyngeal and occipital arteries also enter the foramen. The two jugular foramina lie in line with a line drawn through the centres of the two external auditory meatuses. Following the direction of a line connecting the alar spine of the sphenoid and the mastoid process of the temporal, and placed immediately external to the apertures of the carotid canal and jugular foramen, is the **vaginal process** of the tympanic plate of the temporal bone, the edge of which is sharp and thin, and serves to separate the under surface of the petrous temporal from the non-articular part of the glenoid fossa. Springing from this crest immediately external to the jugular fossa, and in line with the middle of the external auditory meatus, is the **styloid process** (processus styloideum) of the temporal bone

(p. 114). Its relation to the jugular foramen is of great importance, as the internal jugular vein lies immediately to its inner side.

Immediately behind the root of the styloid process, internal to and in line with the front of the mastoid process, is the **stylo-mastoid foramen** (foramen stylo-mastoideum), the lower aperture of the aquæductus Fallopii through which the facial nerve passes out and the stylo-mastoid branch of the posterior auricular artery passes in. The inner surface of the mastoid process is deeply grooved at its base for the origin of the posterior belly of the digastric muscle. Internal to this, and running along just wide of the occipito-mastoid suture, is a shallow groove in which the occipital artery is lodged. Immediately internal to the stylo-mastoid foramen is the synchondrosis between the extremity of the **jugular process** (processus jugularis) of the occipital bone and the petrous temporal. The former is a bar of bone which limits the jugular fossa posteriorly and abuts on the occipital condyles internally; its under surface is convex from before backwards and affords attachment to the rectus lateralis muscle. The **occipital condyles** (condyli occipitales) are placed between the jugular processes and the foramen magnum. Ending in front by a rounded thickening which becomes confluent with the anterior border of the foramen magnum, they form by their inner sides the lateral boundaries of that aperture on its anterior half. Externally they are confluent with the jugular processes, in front of which they overhang a fossa which is pierced behind by the **anterior condylic foramen** (canalis hypoglossi), through which passes the hypoglossal nerve, together with a small vein and occasionally a small meningeal branch derived from the ascending pharyngeal artery.

The **posterior condylic fossæ** are situated just behind the posterior extremities of the condyles. Not unfrequently their floor is pierced by the **posterior condylic foramen** (canalis condyloideus), through which the posterior condylic vein emerges. The base of the skull behind the jugular processes and condyles of the occipital bone is formed by the nuchal surface (planum nuchale) of the tabular plate of that bone. Posteriorly this surface is bounded by the **superior curved line**, in the centre of which is placed the projecting external occipital protuberance. Laterally the tabular plate is separated from the mastoid portion of the temporal bone by the occipito-mastoid suture, which curves backwards and outwards from the extremity of the jugular process in front around the base of the mastoid process behind. In front and in the middle line this plate of bone is pierced by the **foramen magnum**, the anterior half of which has been already seen to lie between the occipital condyles. Usually of oval form, though in some cases it tends to approach the circular, the plane of this opening is inclined downwards and slightly forwards. The extreme anterior edge of the foramen is sometimes called the **basion**, whilst the extreme posterior margin is termed the **opisthion**. The lower border of the medulla oblongata, where it becomes continuous with the spinal cord, is lodged within the foramen, together with the meninges which cover it, whilst the vertebral arteries and the spinal portions of the spinal accessory nerves pass upwards through it. The anterior and posterior spinal arteries, some small veins, and the roots of the first cervical nerves, also traverse it from above downwards.

The student will no doubt experience considerable difficulty in bearing in mind the relative positions of the various foramina and processes which he has studied on the under surface of the base of the skull.

If a line be drawn on either side from the anterior palatine canal in front, through the stylo-mastoid foramina posteriorly, it will be found to cut or pass near to the following objects:—On the hard palate it will lie close to the posterior and accessory palatine canals. It will then pass between the hamular process and the external pterygoid plate overlying the foramen ovale, the foramen spinosum, the opening of the osseous Eustachian canal and the spine of the sphenoid; behind this it will cut through the root of the styloid process and define externally the limits of the jugular fossa. After passing through the stylo-mastoid foramen, if the line be prolonged backwards it will usually be found to pass over the mastoid foramen in the occipito-mastoid suture. Another line of much value is one drawn across the base of the skull from the centre of one external auditory meatus to the other. This will be found to pass through the root of the styloid process, the jugular foramen, the anterior condylic foramen; it then crosses the front of the occipital condyles, and corresponds with the anterior edge of the foramen magnum.

A line which may be found useful is one drawn from the stylo-mastoid foramen of one side to the posterior palatine canal of the opposite side. This will be seen to overlie, from behind forwards, the outer part of the jugular foramen and the inferior opening of the carotid canal.

The line indicates the direction of the carotid canal, and cuts the foramen lacerum medium anteriorly; in front of this it usually corresponds to the position of the posterior aperture of the pterygo-palatine canal.

The examination of the base of the skull is incomplete unless the student examines it with the lower jaw and atlas vertebra in position. The relation of the ramus of the lower jaw to the zygomatic fossa has been already sufficiently studied (p. 153); one or two points, however, may be emphasised. The **alar spine** of the sphenoid lies just internal to the condyle of the jaw when that structure is in position in the articular part of the glenoid fossa, and it is noteworthy that immediately to the inner side of the alar spine is the commencement of the **osseous Eustachian tube.** The root of the **styloid process** occupies the centre of the interval between the mandibular ramus and the front of the mastoid process.

Anteriorly the arcade formed by the **body** of the **lower jaw** adds greatly to the depth of the hard palate. In this space are lodged the tongue and the structures which form the floor of the mouth. The inner surface of each side of the body of the mandible is traversed by the **internal oblique line** (linea mylo-hyoidea), which commences posteriorly just behind the root of the last molar tooth and runs downwards and forwards towards the symphysis in front.

When the **atlas vertebra** is in articulation with the occipital bone it is well to recognise the relation of its **transverse processes** to the surrounding structures. The extremities of these processes lie in line with the ends of the jugular processes of the occipital bone, and thus come to be placed just internal to and immediately below and slightly in front of the tips of the **mastoid processes.** They can thus be easily felt in the living. Anteriorly they are separated by a short interval from the **styloid processes**, and the **stylo-mastoid foramina** lie immediately in front and slightly to the outer side of their extremities. The student will note that there is no hole in the jugular process of the occipital bone corresponding to the arterial foramen in the transverse process of the atlas through which the vertebral artery passes. The course of this vessel over the upper surface of the posterior arch behind the superior articular processes of the atlas will be seen to coincide with the posterior condylic fossæ and the margins of the foramen magnum immediately internal thereto, where a slight grooving of the edge often indicates the course of the artery. In front, the anterior tubercle of the atlas falls in line with the **pharyngeal tubercle** on the under surface of the basioccipital, and the student must not overlook the fact that the anterior surface of the cervical column does not coincide with the anterior margin of the foramen magnum, but lies nearly half an inch in front of that, in a coronal plane passing immediately in front of the external auditory meatus. Behind, the upper surface of the posterior arch of the atlas overlaps the hinder margin of the foramen magnum, and it is by the apposition of these two surfaces that extension is checked at the occipito-atlantal articulation.

THE SKULL IN SECTION.

By the removal of the skull-cap the interior of the cranial cavity is exposed. The deep surface of the cranial vault is grooved mesially for the **superior longitudinal sinus**, on either side of which are seen numerous depressions for the lodgment of Pacchionian bodies. On holding the bone up to the light, the floor of these little hollows is oftentimes seen to be very thin. A short distance in front of the lambda, and on either side of the sagittal suture, are the internal openings of the **parietal foramina.** The inner tables of the frontal and parietal bones are grooved for the meningeal arteries. The principal branch of the **middle meningeal** runs more or less parallel to and at a variable distance behind the line of the coronal suture. Along the bottom of these grooves small foramina may be seen for the passage of nutrient arteries to the bone, and the floor of the longitudinal sinus is likewise pierced by small apertures for the transmission of veins.

The Upper Surface of the Base of the Skull.

Cranial Fossæ.—The upper surface of the base of the skull is divided into

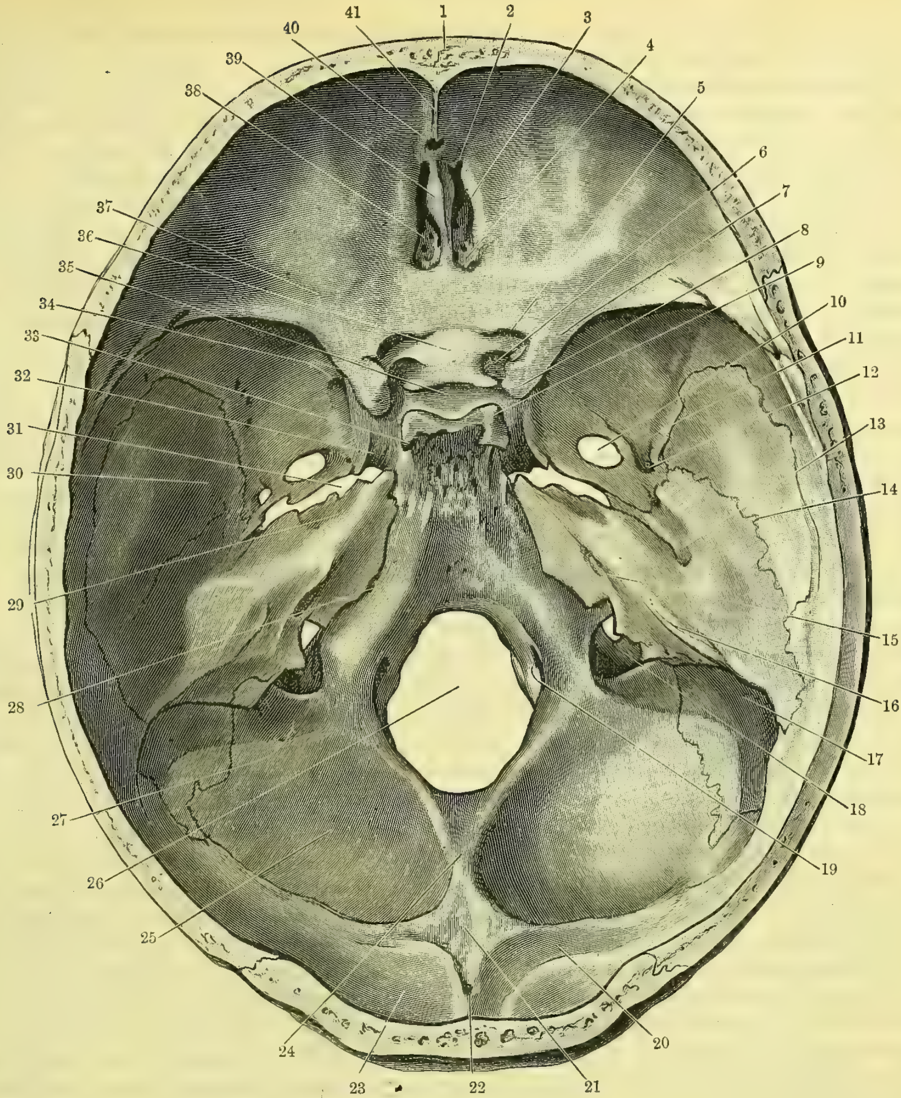


FIG. 117.—BASE OF THE SKULL AS SEEN FROM ABOVE.

1. Frontal bone.
2. Slit for nasal nerve.
3. Anterior ethmoidal foramen.
4. Posterior ethmoidal foramen.
5. Optic foramen.
6. Foramen for internal carotid artery formed by anterior and middle clinoid processes.
7. Lesser wing of sphenoid.
8. Anterior clinoid process, in this case united on its inner side to the middle clinoid process.
9. Posterior clinoid process.
10. Foramen ovale.
11. Groove for middle meningeal artery.
12. Foramen spinosum.
13. Hiatus Fallopii.
14. Line of petro-squamosal suture.
15. Internal auditory meatus.
16. Groove for superior petrosal sinus.
17. Groove for sigmoid part of lateral sinus.
18. Jugular foramen.
19. Anterior condylic foramen.
20. Groove for lateral sinus.
21. Internal occipital protuberance.
22. Ridge for attachment of falx cerebri.
23. Fossa for the lodgment of the occipital lobes of cerebrum.
24. Ridge for the attachment of the falx cerebelli.
25. Fossa for the lodgment of the left cerebellar hemisphere.
26. Foramen magnum.
27. Groove for the sigmoid sinus turning into the jugular foramen.
28. Groove for the inferior petrosal sinus running along the line of suture between the petrous temporal and the basioccipital.
29. Depression for the Gasserian ganglion.
30. Middle cranial fossa for lodgment of temporal lobe of cerebrum.
31. Foramen lacerum medium.
32. Carotid groove.
33. Dorsum sellæ of sphenoid.
34. Leads into foramen rotundum.
35. Pituitary fossa.
36. Olivary eminence of sphenoid.
37. Anterior cranial fossa for lodgment of frontal lobes of cerebrum.
38. Cribriform plate of ethmoid.
39. Crista galli of ethmoid.
40. Foramen cæcum.
41. Crest for attachment of falx cerebri.

three fossæ, of which the cerebrum occupies the anterior and middle, whilst in the posterior is lodged the cerebellum.

The **anterior fossa** is defined posteriorly by the sharp thin edge of the lesser wings of the sphenoid, which curve outwards and slightly upwards as well as backwards to reach the region of the **pterion** externally. The floor is formed from before backwards, in the middle line, by the upper surface of the ethmoid and the fore part of the body of the sphenoid; laterally it is constituted by the orbital plates of the frontal and the lesser wings of the sphenoid. On these the under surface of the frontal lobes of the cerebrum rests. In front the fossa is divided mesially by the **frontal crest**, to which the falx cerebri is attached. This is confluent below with the fore part of the **crista galli**, from which, however, it is separated by the **foramen cæcum**, which usually transmits a small vein from the nose. On either side of the crista galli there are grooves which vary considerably in depth and width: therein are lodged the olfactory lobes. The floor and sides of the groove are pierced by numerous foramina; of these the largest number transmit the olfactory nerves to the nasal fossæ. In front an elongated slit, placed on either side of the crista, affords a passage to the nose for the internal nasal nerve and a small branch of the anterior ethmoidal artery which accompanies it. To the outer side of the olfactory groove and the cribriform plate, the anterior fossæ communicate on either side by means of the two **ethmoidal foramina** with the cavities of the orbits. The anterior foramen transmits the internal nasal nerve and the anterior ethmoidal artery; the posterior affords passage to the posterior ethmoidal artery and the small spheno-ethmoidal nerve of Luschka. External to the olfactory groove, the floor of the fossa, which here corresponds to the roof of the orbit, is very thin, as may be seen by holding the skull up to the light; it is convex from side to side, and bears the impress of the convolutions of the under surface of the frontal lobes of the cerebrum which rest upon it. In front and at the side there are a number of vascular grooves for the branches of the anterior and middle meningeal arteries respectively.

The **middle fossa**, which in form may be compared to the wings of a bird united by the body, is bounded in front by the curved thin posterior edge of the lesser wings of the sphenoid; posteriorly, by the line of attachment of the tentorium cerebelli, extending from the **posterior clinoid process** along the superior border of the petrous portion of the temporal bone. The median part of the fossa, which is narrow, corresponds to the **sella turcica** and the **olivary eminence** of the **sphenoid.** It is limited anteriorly by a line connecting the anterior margins of the two optic foramina, and is overhung behind by the **dorsum sellæ.** In this area are lodged the structures which lie within the interpeduncular space on the base of the brain. The floor of the lateral parts of the fossa on each side is formed by the great wing of the sphenoid in front, the squamous part of the temporal bone to the outer side, and the superior surface of the petrous temporal behind. In the hollows so formed the temporal lobes of the cerebrum are lodged. On either side of the olivary eminence are seen the **optic foramina**; these pass into the orbital cavities and transmit the optic nerves and ophthalmic arteries. Immediately behind these openings the anterior and middle clinoid processes are sometimes united, so as to enclose a foramen. Through this the internal carotid artery passes upwards. Leading backwards from this, along the side of the body of the sphenoid, is the **carotid groove**, which turns downwards near the apex of the petrous temporal, to become continuous with the carotid canal, which here opens on the posterior wall of an irregular aperture, placed between the side of the body of the sphenoid and the summit of the petrous temporal, called the **foramen lacerum medium.** Through the inner angle of this opening the carotid artery accompanied by its plexus of veins and sympathetic nerves passes upwards. Running through the fibrous tissue, which in life blocks up this opening, the large superficial petrosal nerve coming from the hiatus Fallopii passes downwards and forwards to reach the posterior orifice of the **Vidian canal,** which is placed on the anterior and inferior border of the foramen lacerum medium. A small meningeal branch of the ascending pharyngeal artery also passes upwards through this foramen. In front and to the outer side of the foramen lacerum, and separated from it by a narrow bar of bone,

is the **foramen ovale**; through this pass both roots of the inferior maxillary nerve, the small meningeal artery, and some emissary veins. A little external and posterior to this is the **foramen spinosum** for the transmission of the middle meningeal vessels, together with a recurrent branch from the inferior maxillary nerve. Leading from the external extremity of the foramen lacerum there is a groove which passes outwards, backwards, and slightly upwards on the superior surface of the petrous temporal to end in the **hiatus Fallopii** (a cleft opening into the **aquæductus Fallopii**), which gives passage to the large superficial petrosal branch from the geniculate ganglion on the seventh nerve, together with the small petrosal branch of the middle meningeal artery. Just external to the hiatus Fallopii there is another small foramen for the transmission of the lesser superficial petrosal nerve. Overhung by the posterior border of the lesser wing of the sphenoid is the **sphenoidal fissure,** the cleft which separates the lesser from the great sphenoidal wings, and which opens anteriorly into the hollow of the orbit; through this pass the third, fourth, ophthalmic division of the fifth, and sixth nerves, together with the ophthalmic veins as well as the sympathetic filament to the lenticular ganglion. Just below its inner extremity is the **foramen rotundum** for the passage of the superior maxillary nerve to the spheno-maxillary fossa. Behind this, and between it and the foramen ovale, the **foramen Vesalii** may occasionally be seen, through which a vein passes to reach the pterygoid plexus.

The lateral parts of the middle fossa are moulded in conformity with the convolutions of the temporal lobes, but towards their inner sides the splitting of the dura mater in the region of the cavernous sinus serves to separate the cranial base from the under surface of the cerebrum. As may be seen by transmitted light, the floor of the lateral parts of the fossa is thin as it overlies the **temporal, zygomatic,** and **glenoid fossæ.** The grooves for the lodgment of the branches of the middle meningeal artery leading from the foramen spinosum are readily seen; one, coursing backwards a little below the line of the squamoso-parietal suture, is specially well marked. Amongst other features may be noticed the depression for the lodgment of the **Gasserian ganglion** overlying the summit of the petrous temporal; behind and to the outer side of the hiatus Fallopii, the **arcuate eminence,** indicating the position of the superior semicircular canal; and immediately anterior and slightly to the outer side of this the **tegmen tympani**, which roofs in the cavity of the tympanum, the thinness of which can readily be demonstrated if light be allowed to fall through the external auditory meatus.

The **posterior fossa** is larger and deeper than the others. In front it is limited by a line on either side leading backwards and outwards from each **posterior clinoid process** along the superior border of the petrous part of the temporal bone, where externally and posteriorly it becomes confluent with the superior lip of the transverse groove for the **lateral sinus,** ending posteriorly in the middle line at the **internal occipital protuberance.** Along the line thus indicated the process of dura mater called the **tentorium cerebelli,** which roofs in the posterior fossa, is attached. The floor of the fossa, in which the cerebellar lobes, the pons, and medulla are lodged, is formed by the petrous and mastoid portions of the temporal bone, with part of the body of the sphenoid and the basilar portion of the occipital bone wedged in between them. Above the mastoid temporal a small part of the posterior inferior angle of the parietal enters into the constitution of the outer wall of the fossa. Behind and within these the lateral parts and lower portions of the squamous occipital complete the floor. In the middle line the floor of the fossa is pierced by the **foramen magnum**, in which lies the lower part of the medulla, together with its membranes, and through which pass upwards the vertebral arteries and the spinal accessory nerves. On either side of the foramen magnum, and a little in front of a transverse line passing through its centre, is the opening of the **anterior condylic foramen** for the passage of the hypoglossal nerve, a small meningeal branch from the ascending pharyngeal artery and an emissary vein. Overhanging the opening of the anterior condylic foramen there is a thickened rounded bridge of bone, to the outer side of which is placed the irregular opening of the **jugular foramen** (foramen lacerum posterius). The size of this is apt to vary on the two sides, and the lumen is frequently subdivided by a spicule of bone which

runs across it; the posterior and external rounded part of the foramen is occupied by the lateral sinus, which here joins the internal jugular vein. A meningeal branch from the ascending pharyngeal or occipital artery also enters the skull through this compartment. The fore and internal part of the foramen is confluent with the groove for the **inferior petrosal sinus**, which turns downwards in front of the spicule above referred to. The interval between the portions of the foramen occupied by the two veins allows of the transmission of the glosso-pharyngeal, vagus, and spinal accessory nerves in order from before backwards. About a quarter of an inch above and to the outer side of the fore part of the foramen jugulare the posterior surface of the petrous portion of the temporal bone is pierced by the **internal auditory meatus,** through which the facial and auditory nerves, together with the pars intermedia of Wrisberg, and the auditory branch of the basilar artery leave the cranial cavity. Behind the jugular foramen and close to the margin of the foramen magnum the opening of the **posterior condylic foramen**, when present, may be seen. This gives passage to a vein which joins the vertebral vein inferiorly. The internal aperture of the **mastoid foramen** is noticed opening into the groove for the lateral sinus, a little below the level of the superior border of the petrous temporal. Through it passes an emissary vein which joins the occipital vein externally; the mastoid branch of the occipital artery also enters the cranial cavity through this foramen.

The posterior fossa is divided into two halves posteriorly by the **internal occipital crest,** to which the falx cerebelli is attached, the floors of the hollows on either side of which are often exceedingly thin and are for the lodgment of the lateral lobes of the cerebellum. The grooves for the following blood sinuses are usually distinct—the **superior petrosal** running along the superior border of the petrous temporal; the **inferior petrosal** lying along the line of suture between the petrous temporal and basilar process of the occipital bone; the **occipital sinus** grooving the internal occipital crest; and the **lateral sinus** curving forwards and outwards from the internal occipital protuberance, across the internal surface of the squamous occipital, to reach the posterior inferior angle of the parietal bone, in front of which it turns downwards and inwards to reach the jugular foramen, describing a sigmoid curve, and grooving deeply the inner surface of the mastoid and posterior aspect of the petrous portions of the temporal bone. Before it terminates at the jugular foramen it again reaches the occipital bone and channels the upper surface of the jugular process of that bone. Slight grooves for meningeal arteries are also seen—some pass upwards, whilst others turn downwards and are occupied by branches from the posterior offsets of the middle meningeal arteries.

Mesial Sagittal Section of the Skull.

Such a section should be made a little to one or other side of the mesial plane, so as to pass through the nasal fossæ lateral to the septum; one half will then display the nasal septum in position, whilst in the other the outer wall of the nasal fossa of that side will be exposed.

The form of the cranial cavity is of course subject to many variations dependent on individual and racial peculiarities. The following details are, however, worthy of note. The hinder border of the foramen magnum (**opisthion**), and consequently the floor of the posterior cranial fossa occupies the same horizontal plane as the hard palate. The anterior border of the foramen magnum (**basion**) lies a little higher, so that the plane of the foramen is, in the higher races at least, oblique, and is directed downwards and slightly forwards. From the basion, a line passing upwards and forwards to reach the suture between the sphenoid and ethmoid passes through the **basicranial axis** formed by the basioccipital, the basisphenoid, and the presphenoid. The basicranial axis is wedge-shaped on section posteriorly, whilst anteriorly it is of considerable width, and has within it the large sphenoidal air sinus. Its upper surface leads upwards and forwards with a varying degree of obliquity from the basion to the overhanging edge of the dorsum sellæ, in front of which the **pituitary fossa,** the floor of which is quite thin, is well seen in the section.

From the olivary eminence the floor of the anterior fossa follows a more or less horizontal direction, corresponding pretty closely to the level of the axis of the orbital cavity. The roof of the orbit is seen to bulge upwards to a considerable extent into the floor of the anterior fossa; whilst the floor of the middle fossa sinks to a level corresponding

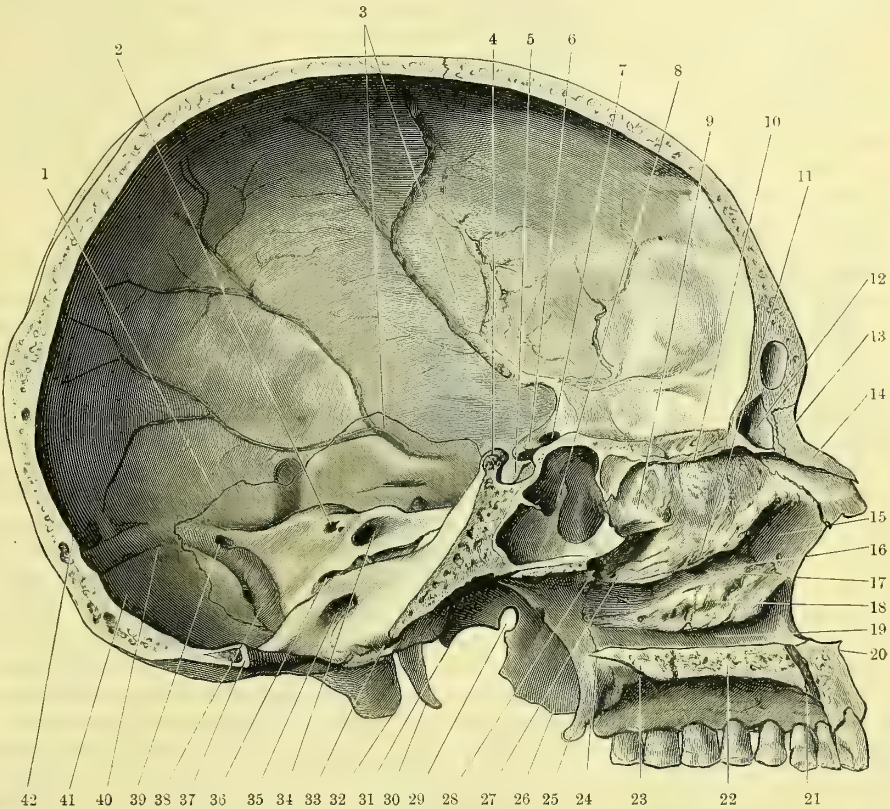


FIG. 118.—INNER ASPECT OF LEFT HALF OF SKULL SAGITTALLY DIVIDED.

1. Suture between parietal and temporal bones.
2. Remains of the subarcuate fossa.
3. Grooves for branches of the middle meningeal artery.
4. Dorsum sellæ.
5. Pituitary fossa.
6. Anterior clinoid fossa.
7. Optic foramen.
8. Sphenoidal sinus.
9. Nasal surface of superior turbinated bone.
10. Cribriform plate of ethmoid.
11. Nasal surface of middle turbinated bone.
12. Frontal sinus.
13. Nasal spine of frontal.
14. Nasal bone.
15. Nasal process of superior maxilla.
16. Middle meatus of nose.
17. Directed towards opening of antrum.
18. Nasal surface of inferior turbinated bone.
19. Inferior meatus of nose.
20. Anterior nasal spine.
21. Anterior palatine canal.
22. Palatal process of superior maxilla.
23. Palatal process of palate bone.
24. Posterior nasal spine.
25. Hamular process of internal pterygoid plate.
26. External pterygoid plate.
27. Superior meatus of nose.
28. Spheno-palatine foramen.
29. Pterygo-spinous ligament almost completely ossified to enclose a foramen.
30. Styloid process of temporal bone.
31. Alar spine of sphenoid.
32. Mastoid process.
33. Basion (mid-point of anterior border of foramen magnum).
34. Internal auditory meatus.
35. Anterior condylic foramen.
36. Leading into jugular foramen.
37. Opisthion (mid-point of posterior border of foramen magnum).
38. Groove for sigmoid sinus.
39. Opening of mastoid foramen.
40. For lateral sinus and attachment of tentorium cerebelli.
41. Fossa for lodgment of cerebellar hemisphere.
42. Internal occipital protuberance.

to that of the under surface of the basicranial axis, where it forms the roof of the posterior nares. The maximum length of the skull is measured from the **glabella** (a point between the superciliary ridges) to the occipital point posteriorly. It is noteworthy that the maximum occipital point does not necessarily correspond to the external occipital protuberance (**inion**). The greatest vertical height usually corresponds to the distance from the **basion** to the **bregma** (point of union of the sagittal with the coronal suture), though

to this rule there are many exceptions. On looking into the posterior fossa the anterior condylic and jugular foramina and the internal auditory meatus are seen in line, sloping from below upwards. The **internal auditory meatus** lies in a vertical plane, passing through the basion. The grooves for the middle meningeal artery and its branches are very obvious. The anterior groove curves forwards and outwards, and reaching the inner surface of the pterion, passes towards the vertex at a variable distance behind and more or less parallel to the coronal suture. From this, grooves pass forwards across the suture to reach the frontal bone. Another groove curves upwards and backwards a little below the line of the parieto-squamosal suture. From this, an upwardly-directed branch radiates on the inner surface of the parietal bone, in the region of the parietal eminence, whilst a lower branch passes backwards some little distance above the lambdoid suture, and gives offsets which curve downwards and inwards over the inner surface of the squamous portion of the occipital bone.

Nasal Fossæ.—In the section through the **nasal fossa** the structures which form its *outer wall* can now be studied. These are—the nasal bone; the nasal process of the superior maxilla; the lachrymal bone; the lateral mass of the ethmoid, comprising the superior and middle turbinated bones; the vertical plate of the palate bone; the inferior turbinated bone; and the mesial surface of the internal pterygoid plate. The *roof* as seen in the section is formed by the nasal and frontal bones, the cribriform plate of the ethmoid, the body of the sphenoid and the sphenoidal turbinals, the sphenoidal process of the palate and the ala of the vomer. The *floor*, which is nearly horizontal from before backwards, is formed by the palatal processes of the superior maxilla and palate bones. On sagittal section the **nasal fossa** appears somewhat triangular in shape with the angles cut off; the base corresponds to the floor; the anterior and posterior nares to the truncated anterior and posterior angles respectively; the superior angle is cut off by the cribriform plate; whilst the sides correspond to the frontal and nasal bones anteriorly, and the sphenoidal turbinals, sphenoidal process of the palate, and the ala of the vomer posteriorly. The cavity is therefore deep towards its middle, but gradually becomes shallower in front and behind where the openings of the nares are situated. The opening of the **anterior naris,** which is of half-heart shape, is larger than that of the **posterior naris,** and is directed forwards and downwards; the opening of the posterior is of rhomboidal form, and slopes backwards and downwards. The **inferior meatus** is the channel which is overhung by the inferior turbinated bone, and its floor is formed by the side-to-side concavity of the upper surface of the hard palate. Opening into it above, under cover of the fore part of the inferior turbinated bone, is the **canal** for the **nasal duct**; whilst its floor is pierced in front near the middle line by the **anterior palatine canal.** The **middle meatus** is the hollow between the middle and inferior turbinated bones; it slopes from above downwards and backwards, and is overhung by the free curved edge of the middle turbinal, beneath which there is a passage called the **infundibulum,** leading upwards and forwards to open superiorly into the frontal sinus, as well as into some of the anterior ethmoidal cells. Under cover of the centre of the middle turbinated bone there is an irregular opening leading into the **maxillary sinus** or antrum of Highmore, and there are frequently independent openings for the middle and some of the anterior ethmoidal cells. The **superior meatus,** about half the length of the middle meatus, is placed between the superior and middle turbinated bones in the back and upper part of the fossa; it receives the openings of the **posterior ethmoidal cells.** Near its posterior extremity the **spheno-palatine foramen** pierces its outer wall, and brings it in relation with the spheno-maxillary fossa. The **sphenoidal sinus** opens on the roof of the nose, above the level of the superior turbinated bone, into a depression called the **spheno-ethmoidal recess.**

Nasal Septum.—If the opposite half of the section in which the osseous **nasal septum** is retained be now studied, it will be seen to be formed by the crests of the superior maxillary and palate bones below, on which rests the vomer, the posterior border of which being free, forms the posterior edge of the nasal septum, which slopes obliquely upwards and backwards towards the under surface of the body of the sphenoid. Here the vomer articulates with the rostrum of the sphenoid. In front of this the vomer articulates with the perpendicular plate of the ethmoid,

between which anteriorly there is an angular recess into which the cartilaginous septum fits. Superiorly and anteriorly the osseous septum is completed by the articulation of the perpendicular plate of the ethmoid with the nasal process of the frontal, together with the nasal crest formed by the union of the nasal bones; whilst posteriorly and superiorly the perpendicular plate of the ethmoid articulates with the mesial ethmoidal crest of the sphenoid. In most instances the osseous septum is not perfectly vertical, but is deflected towards one or other side.

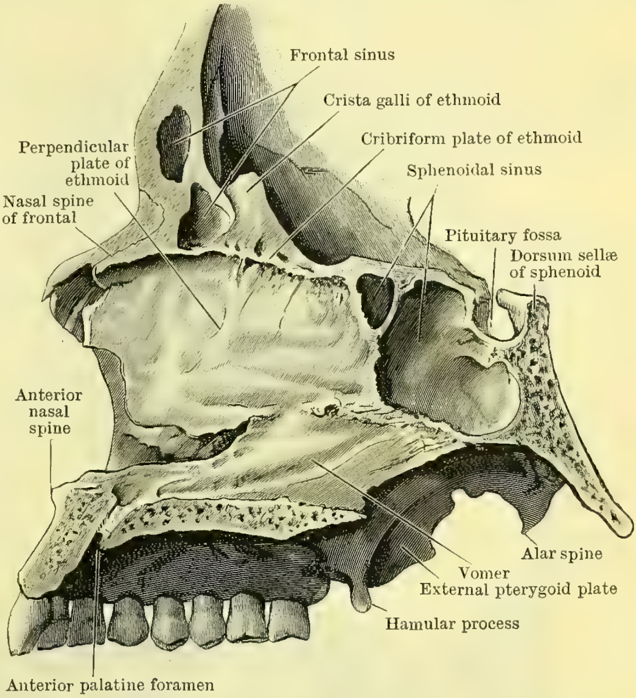


FIG. 119.—NASAL SEPTUM AS SEEN FROM THE LEFT SIDE.

Air-sinuses in connexion with the Nasal Fossæ.—Connected with the nasal fossæ are a number of air-sinuses. These are found within the body of the sphenoid, the lateral mass of the ethmoid, the orbital process of the palate bone, the body of the superior maxilla, and the superciliary arch of the frontal bone.

The **sphenoidal sinus**, of variable size, occupies the interior of the body of the sphenoid. In some cases it extends towards the roots of the pterygoid processes. In front it is formed in part by the absorption of the sphenoidal spongy bones, and is divided up into two cavities by a sagittally-placed partition, which, however, is frequently displaced to one or other side. It opens anteriorly into the roof of the nose in the region of the spheno-ethmoidal recess.

The **ethmoidal sinuses** are placed between the lateral aspects of the upper part of the nasal fossæ, and the cavities of the orbit, from which they are separated by thin and papery walls. These air spaces are completed by the articulation of the ethmoid with the superior maxilla, lachrymal, frontal sphenoid, and palate bones, and are divided into three groups—an anterior, middle, and posterior. The latter communicates with the superior meatus; the anterior and middle open either independently or in conjunction with the infundibulum into the middle meatus.

The **sinus** in the orbital process of the **palate bone** either communicates with the sphenoidal sinus, or else assists in closing in some of the posterior ethmoidal cells. Its communication with the nasal fossa is through one or other of these spaces.

The **maxillary sinus** or **antrum** of **Highmore** lies to the outer side of the nasal fossæ, occupying the body of the superior maxilla. Its walls, which are relatively thin, are directed upwards to the orbit, forwards to the face, backwards to the zygomatic and spheno-maxillary fossa, and inwards to the nose. In the latter situation the vertical plate of the palate bone, the uncinate process of the ethmoid, the maxillary process of the inferior turbinated bone, and a small part of the lachrymal bone assist in the formation of the thin osseous partition which separates it from the nasal fossa. The floor corresponds to the alveolar border of the jaw, and differs from the other walls in being stout and thick; it is, however, deeply pitted inferiorly by the alveoli for the teeth. The antrum opens by a narrow orifice into the middle meatus.

The **frontal sinuses** lie, one on either side, between the inner and outer tables of the frontal bone over the root of the nose, and extend outwards under the superciliary arches. The partition which separates them is usually central, though it

may be deflected to one or other side. They communicate with the nose through a passage called the **infundibulum**, which opens inferiorly into the fore part of the middle meatus.

The fact should not be overlooked that the air spaces within the temporal bone, viz. the tympanic cavity and the mastoid air cells, are brought into communication with the naso-pharynx through the Eustachian tubes. For further details regarding the air-sinuses and the mode of their growth, consult the description of the individual bones.

Coronal Sections.

The relations of many parts of the cranium are well displayed in a series of coronal sections.

By sawing off a thin slice from the front of the lower part of the frontal bone above, and carrying the section downwards through the inner wall of the orbit and

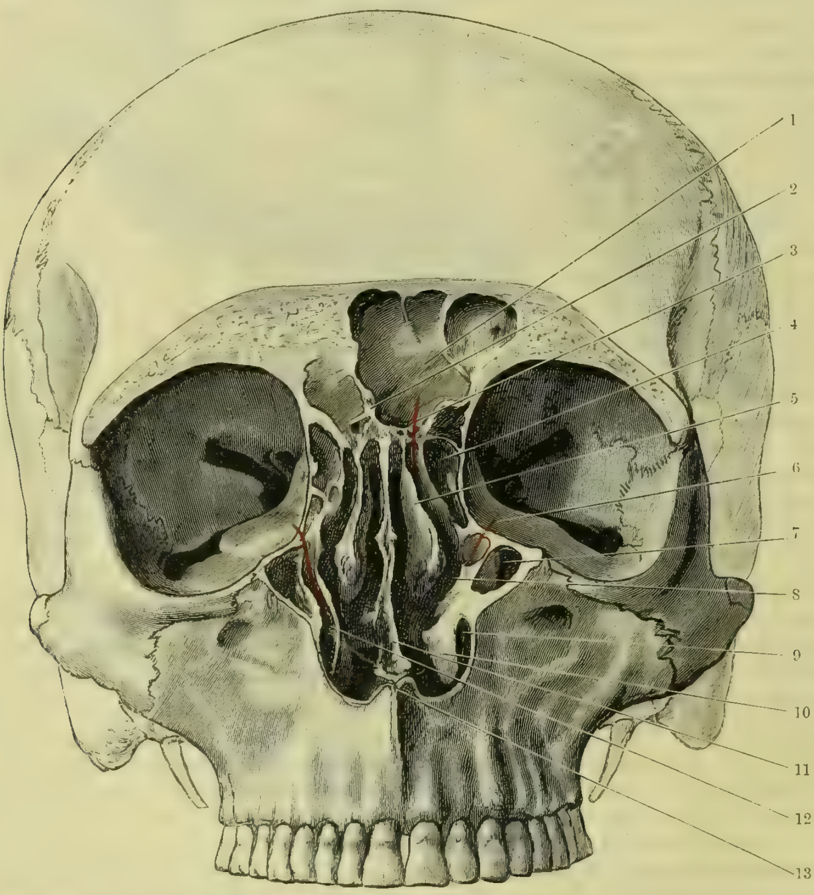


Fig. 120.—Part of the Frontal, Nasal, and Superior Maxillary Bones removed in order to display the Relation of the various Cavities exposed.

1. Frontal sinus.
2. Septum of frontal sinus deflected towards the right.
3. Infundibulum leading from sinus to middle meatus.
4. Anterior ethmoidal air sinuses.
5. Middle turbinated bone.
6. Red line in upper part of osseous canal for nasal duct, laid open throughout its entire length on the right side.
7. Cavity of antrum laid open.
8. Middle meatus of nose.
9. Inferior meatus of nose.
10. Inferior turbinated bone.
11. Nasal septum.
12. Canal for nasal duct laid open throughout its entire length.
13. Anterior nasal spine.

the nasal process of the superior maxilla, into the anterior nares below, a number of important relations are revealed (see Fig. 120). In the frontal region the extent and arrangement of the **frontal sinuses** are displayed. The partition between the two sinuses, be it noted, is usually complete and central in position, though it may occasionally be

perforated or oblique. The sinuses are hardly ever symmetrical, the right being usually the smaller of the two (Logan Turner, *Edin. Med. Journ.* 1898).

The **infundibulum** on either side, leading from the frontal sinus above to the middle meatus below, is seen with the middle turbinated bone internal to it, and the anterior ethmoidal cells to its outer side above. If the section passes through the **canal** for the **nasal duct** the continuity of that channel leading from the orbit above to the inferior meatus of the nose below is clearly shown. Its inner wall above, by which it is separated from the cavity of the nose, is formed by the thin lachrymal bone; below, it passes under cover of the inferior turbinated bone to open into the fore part of the inferior meatus. It is separated from the antrum externally by a thin lamina of bone. The cavity of the antrum is seen to extend upwards and forwards so as to pass over the outer side as well as slightly in front of the canal for the nasal duct.

The lower margins of the middle turbinated bones lie pretty nearly on a level with the most dependent parts of the orbital margins, whilst the lower borders of the inferior turbinals are placed a little above the lower margin of the anterior nares on a level with the lowest point of the malo-maxillary suture.

Such a section will reveal any deflection of the nasal septum should it exist, and will also show that but a narrow cleft separates the upper part of the septum, on either side, from the inner surface of the superior turbinals.

The next section (Fig. 121) passes through the fore part of the temporal fossa just behind the external angular process of the frontal bone above; inferiorly it passes through the alveolar process of the upper jaw in the interval between the first and second molar teeth. The cranial, orbital, nasal, and maxillary cavities are all exposed, together with the roof of the mouth.

The **anterior cranial fossa** is deepest in its centre, where its floor is formed by the cribriform plate of the ethmoid; this corresponds to the level of the fronto-malar suture externally. On either side the floor of the fossa bulges upwards, owing to the arching of the roof of the orbit. Of the orbital walls, the external is the thickest and stoutest; the superior, internal, and inferior walls, which separate the orbit from the cranial cavity, the

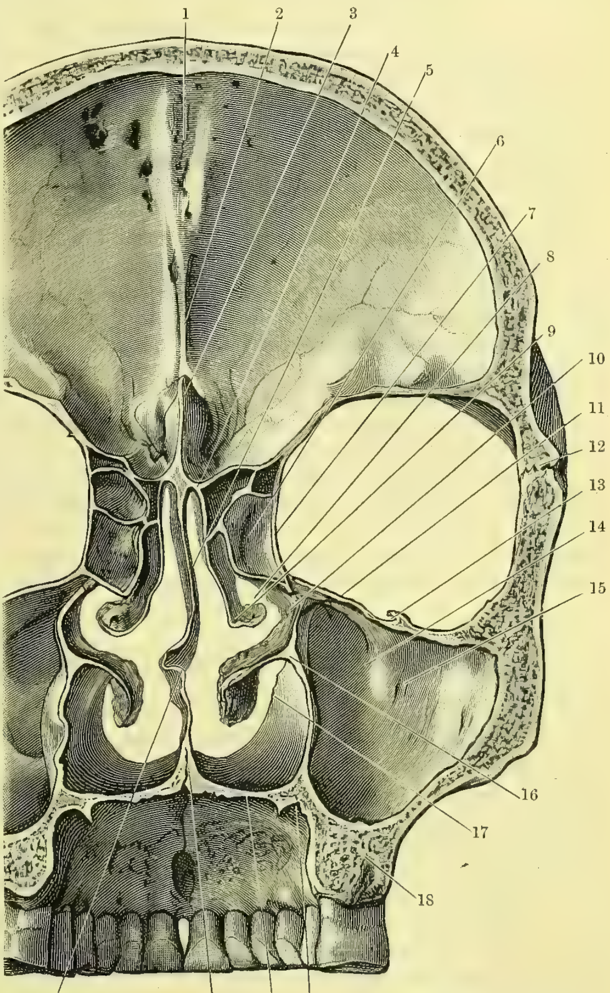


Fig. 121.—Coronal Section passing inferiorly through Interval between First and Second Molar Teeth.

1. Groove for superior longitudinal sinus.
2. Crest for attachment of falx cerebri.
3. Crista galli of ethmoid.
4. Cribriform plate of ethmoid.
5. Perpendicular plate of ethmoid, assisting in the formation of nasal septum.
6. Lateral mass of ethmoid consisting of the ethmoidal cells.
7. Os planum of ethmoid.
8. Middle meatus of nose.
9. Middle turbinated bone.
10. Opening from middle meatus into antrum.
11. Orbital plate of superior maxilla.
12. Fronto-malar suture.
13. Infraorbital groove.
14. Antrum or maxillary sinus.
15. Canal for the anterior dental nerve and vessels exposed.
16. Inferior turbinated bone.
17. Inferior meatus of nose.
18. Alveolar process of superior maxilla.
19. Groove for anterior palatine nerve and vessels.
20. Palatal process of superior maxilla.
21. Maxillary crest forming part of nasal septum.
22. Vomer forming part of nasal septum.

ethmoidal cells, and the antrum, respectively, are all thin. The cavity of the **maxillary sinus** lying to the outer side of the nasal fossæ is well seen. Its roof, which separates it from the orbital cavity, is thin and traversed by the **infraorbital canal.** Its inner wall, with which the inferior turbinal articulates, is very slender, and forms the outer walls of both the middle and inferior meatuses of the nose. Its outer wall is stouter where it arches up to bracket the zygomatic or malar process. Its floor, which rests upon the upper surface of the alveolar border of the upper jaw, sinks below the level of the hard palate. The fangs of the teeth sometimes project into the floor of the cavity.

The **nasal fossæ** are narrow above, where they lie between the orbital cavities, from which they are separated by the cells within the lateral mass of the ethmoid. The roof which corresponds to the cribriform plate is narrow, and lies between the septum mesially and the lateral masses on either side.

At the level of the orbital floor the nasal fossæ expand laterally, the **middle meatus** running longitudinally in the angle formed by the lateral mass of the ethmoid with the body of the superior maxilla, overhung by the middle turbinated bone. This channel is seen to have the ethmoidal cells superior to it, the orbital cavity above and to the outer side, the antrum externally, whilst its floor is formed by the upper surface of the inferior turbinated bone.

The **inferior meatus**, much more roomy, runs along under cover of the inferior turbinated bone. Externally it is related to the antrum, whilst its floor is formed by the concave superior surface of the hard palate.

The **hard palate** is arched below, whilst its superior surface is concave upwards on either side of the median crest which supports the nasal septum. The sides of the arch below correspond to the inner surfaces of the alveolar processes and fall in line with the outer walls of the nasal fossæ superiorly. The summit of the arch lies a quarter of an inch above the level of the floor of the antrum.

SEXUAL DIFFERENCES IN THE SKULL.

Whilst it is a matter of difficulty, in all cases, to determine with certainty the sex of a skull, the following points of difference are usually fairly characteristic. The female skull is, as a rule, smaller than the male. In point of cranial capacity it averages about a tenth less than the male of corresponding race. It is lighter, smoother as regards the development of its muscular ridges, and possesses less prominent mastoid processes. In the frontal region, the superciliary ridges are less pronounced, and this imparts a thinness and sharpness to the upper orbital margin, which is fairly characteristic, and can best be appreciated by running the finger along that edge of bone. For the same reason, the forehead appears more vertical and the projections of the frontal eminences more outstanding, though it is stated that the frontal and occipital regions are less capacious proportionately than in the male. The vertex in the female is said to be more flattened, and the height of the skull consequently somewhat reduced. In man the edge of the tympanic plate is generally sharp, and divides to form the sheath of the styloid process, whilst in the female the corresponding border is stated to be rounder and more tubercular.

Whilst it is true that no one of these differences is sufficiently characteristic to enable us to pronounce with certainty on the matter of sex, it is the case that, taken together, they usually justify us in arriving at a conclusion which, as a rule, may be regarded as fairly accurate. In some instances, however, it is impossible to express any definite opinion.

DIFFERENCES DUE TO AGE.

At birth the face is proportionately small as compared with the cranium, constituting about one-eighth of the bulk of the latter. In the adult the face equals at least half the cranium. About the age of puberty the development and expansion of some of the air-sinuses, more particularly the frontal sinus, lead to characteristic differences in head and face form.

The eruption of the teeth in early life and adolescence enables us to determine the age with fair accuracy. After the completion of the permanent dentition, the wear of the teeth may assist us in hazarding an approximate statement. The condition of the sutures, too, may guide us, synostosis of the coronal and sagittal sutures not as a rule taking place till late in life. Complete obliteration of the synchondrosis between the occipital bone and sphenoid may be regarded as an indication of maturity. In old age the skull usually becomes lighter and the cranial bones thinner. The alveolar borders of the

superior and inferior maxillæ become absorbed owing to the loss of the teeth. This gives rise to a flattening of the vault of the hard palate and an alteration in the form of the lower jaw, whereby the mandibular angle becomes more obtuse.

CRANIOLOGY.

The various groups of mankind display in their physical attributes certain features which are more or less characteristic of the stock to which they belong. Craniology deals with these differences so far as they affect the skull. The method whereby these differences are recorded involves the accurate measurement of the skull in most of its details. Such procedure is included under the term craniometry. Here only the outlines of the subject are briefly referred to; for such as desire fuller information on the subject, the works of Broca, Topinard, Flower, and Turner may be consulted.

The races of man display great variations in regard to the size of the skull. Apart altogether from individual differences and the proportion of head-size to body-height, it may be generally assumed that the size of the skull in the more highly civilised races is much in excess of that displayed in lower types. The size of the head is intimately correlated with the development of the brain. By measuring the capacity of that part of the skull occupied by the encephalon, we are enabled to form some estimate of the size of the brain. The **cranial capacity** is determined by filling the cranial cavity with some suitable material and then taking the cubage of its contents. Various methods are employed, each of which has its advantage. The use of fluids, which of course would be the most accurate, is rendered impracticable, without special precautions, owing to the fact that the macerated skull is pierced by so many foramina. As a matter of practice, it is found that leaden shot, glass beads, or seeds of various sorts are the most serviceable. The results obtained display a considerable range of variation. For purposes of classification and comparison, skulls are grouped according to their **cranial capacity** into the following varieties :—

Microcephalic skulls are those with a capacity below 1350 c.c., and include such well-known races as Andamanese, Veddahs, Australians, Bushmen, Tasmanians, etc.

Mesocephalic skulls range from 1350 c.c. to 1450 c.c., and embrace examples of the following varieties : American Indians, Chinese, some African Negroes.

Megacephalic skulls are those with a capacity over 1450 c.c., and are most commonly met with in the more highly civilised races : Mixed Europeans, Japanese, Eskimo, etc.

Apart from its size, the form of the cranium has been regarded as an important factor in the classification of skulls; though whether these differences in shape have not been unduly emphasised in the past is open to question.

The relation of the breadth to the length of the skull is expressed by means of the **cephalic index** which records the proportion of the maximum breadth to the maximum length of the skull, assuming the latter equal 100, or—

$$\frac{\text{Max. length} \times 100}{\text{Max. breadth}} = \textbf{Cephalic index.}$$

The results are classified into three groups :—

1. **Dolichocephalic**, with an index below 75 : Australians, Kaffirs, Zulus, Eskimo, Fijians.
2. **Mesaticephalic**, ranging from 75 to 80 : Europeans (mixed), Chinese, Polynesians (mixed).
3. **Brachycephalic**, with an index over 80 : Malays, Burmese, American Indians, Andamanese.

In order to provide for uniformity in the results of different observers, some system is necessary by which the various points from which the measurements are taken must correspond. Whilst there is much difference in the value of the measurements insisted on by individual anatomists, all agree in endeavouring to select such points on the skull as may be readily determined, and which have a fairly fixed anatomical position. The more important of these "fixed points" are included in the subjoined table :—

Nasion.—The middle of the naso-frontal suture.

Glabella.—A point midway between the two superciliary ridges.

Ophryon.—The central point of the narrowest transverse diameter of the forehead, measured from one temporal line to the other.

Inion.—The external occipital protuberance.

Maximum Occipital Point.—The point on the occipital squama in the sagittal plane most distant from the glabella.

Opisthion.—The middle of the posterior margin of the foramen magnum.

Basion.—The middle of the anterior margin of the foramen magnum.

Bregma.—The point of junction of the coronal and sagittal sutures.

Alveolar Point.—The centre of the anterior margin of the upper alveolar margin.

Subnasal Point.—The middle of the inferior border of the anterior nasal aperture at the centre of the nasal spine.

Vertex.—The summit of the cranial vault.

Obelion.—A point over the sagittal suture, on a line with the parietal foramina.

Lambda.—The meeting-point of the sagittal and lambdoid sutures.

Pterion.—The region of the antero-lateral fontanelle where the angles of the frontal, parietal, squamous temporal, and alisphenoid lie in relation to one another. As a rule, the sutures are arranged like the letter H, the parietal and alisphenoid separating the frontal from the squamous temporal. In other cases the form of the suture is like an X; whilst in a third variety the frontal and squamous temporal articulate with each other, thus separating the alisphenoid from the parietal.

Asterion is the region of the postero-lateral fontanelle where the lambdoid, parieto-mastoid, and occipito-mastoid sutures meet.

Stephanion.—The point where the coronal suture crosses the temporal crest.

Dacryon.—The point where the vertical lachrymo-maxillary suture meets the fronto-nasal suture at the inner angle of the orbit.

Jugal Point.—Corresponds to the angle between the vertical border and the margin of the zygomatic process of the malar bone.

Gonion.—The outer side of the angle of the inferior maxilla.

The measurements of the length of the skull may be taken between a variety of points—the nasion, glabella, or ophryon in front, and the inion or maximum occipital point behind. Or the maximum length alone may be taken without reference to any fixed points. In all cases it is better to state precisely where the measurement is taken. The maximum breadth of the head is very variable as regards its position; it is advisable to state whether it occurs above or below the parieto-squamosal suture. The inter-relation of these measurements as expressed by the cephalic index has been already referred to. The width of the head may also be measured from one asterion to the other, **biasterionic width**, or by taking the **bistephanic diameter.**

The height of the cranium is usually ascertained by measuring the distance from the basion to the bregma. The relation of the height to the length may be expressed by the **height** or **vertical index,** thus—

$$\frac{\text{Height} \times 100}{\text{Length}} = \textbf{Vertical index.}$$

Skulls are classified in accordance with the relations of length and height as follows:—

Tapeinocephalic index below 72.		**Chamæcephalic** index up to 70.
Metriocephalic index between 72 and 77.	or	**Orthocephalic** index from 70·1 to 75.
Akrocephalic index above 77 (Turner).		**Hypsicephalic** index 75·1 and upwards (Kollmann, Ranke, and Virchow).

The **horizontal circumference** of the cranium, which ranges from 450 mm. to 550 mm., is measured around a plane cutting the glabella or ophryon anteriorly, and the maximum occipital point posteriorly. The **longitudinal arc** is measured from the nasion in front to the opisthion behind; if to this be added the basinasal length and the distance between the basion and the opisthion, we have a record of the vertico-mesial circumference of the cranium. This may further be divided by measuring the lengths of the frontal, parietal, and occipital portions of the superior longitudinal arc. In this way the relative proportions of these bones may be expressed.

The measurements of the skeleton of the face are more complex, but, on the whole, of greater value than the measurements of the cranium. It is in the face that the characteristic features of race are best observed, and it is here that osseous structure most accurately records the form and proportions of the living.

The form of the face varies like that of the cranium in the relative proportions of its length and breath. Generally speaking, a dolichocephalic cranium is associated with a long face, whilst the brachycephalic type of head is correlated with a rounder and shorter face. This rule, however, is not universal, and there are many exceptions to it.

The determination of the facial index varies according to whether the measurements are made with or without the mandible in position. In the former case the length is measured from the ophryon or nasion above to the mental tubercle below, and compared with the maximum bizygomatic width. This is referred to as the **total facial index**, and is obtained by the formula—

$$\frac{\text{Ophryomental length} \times 100}{\text{Bizygomatic width}} = \textbf{Total facial index.}$$

More usually, however, owing to the loss of the lower jaw, the proportions of the face are expressed by the **superior facial index.** This is determined by comparing the ophryo-alveolar or naso-alveolar length with the bizygomatic width, thus—

$$\frac{\text{Ophryo-alveolar length} \times 100}{\text{Bizygomatic width}} = \textbf{Superior facial index.}$$

The terms **dolichofacial** or **leptoprosope** and **brachyfacial** or **chamœprosope** have been employed to express the differences thus recorded.

Uniformity in these measurements, however, is far from complete since many anthropologists compare the width with the length = 100.

The proportion of the face-width to the width of the calvaria is roughly expressed by the use of the terms **cryptozygous** and **phænozygous** as applied to the skull. In the former case the zygomatic arches are concealed, when the skull is viewed from above, by the overhanging and projection of the sides of the cranial box; in the latter instance, owing to the narrowness of the calvaria, the zygomatic arches are clearly visible.

The projection of the face, so characteristic of certain races (Negroes for example), may be estimated on the living by measuring the angle formed by two straight lines, the one passing from the middle of the external auditory meatus to the lower margin of the septum of the nose; the other drawn from the most prominent part of the forehead above to touch the incisor teeth below. The angle formed by the intersection of these two lines is called the **facial angle** (Camper), and ranges from 62° to 85°. The smaller angle is characteristic of a muzzle-like projection of the lower part of the face. The larger angle is the concomitant of a more vertical profile. The degree of projection of the upper jaw in the macerated cranium is most readily determined by employing the **gnathic** or **alveolar index** of Flower. This expresses the relative proportions of the basialveolar and basinasal lengths, the latter being regarded as = 100, thus—

$$\frac{\text{Basialveolar length} \times 100}{\text{Basinasal length}} = \textbf{Gnathic index.}$$

The results are conveniently grouped into three classes :—

Orthognathous, index below 98 : including mixed Europeans, ancient Egyptians, etc.
Mesognathous, index from 98 to 103 : Chinese, Japanese, Eskimo, Polynesians (mixed).
Prognathous, index above 103 : Tasmanians, Australians, Melanesians, various African Negroes.

The form of the nasal aperture in the macerated skull is of much value from an ethnic standpoint, as it is so intimately associated with the shape of the nose in the living. The greatest width of the nasal aperture is compared with the nasal height (measured from the nasion to the lower border of the nasal aperture) and the **nasal index** is thus determined :—

$$\frac{\text{Nasal width} \times 100}{\text{Nasal height}} = \textbf{Nasal index.}$$

Skulls are—

Leptorhine, with a nasal index below 48 : as in mixed Europeans, ancient Egyptians, American Indians, etc.
Mesorhine, with an index ranging from 48 to 53 : as in Chinese, Japanese, Malays, etc.
Platyrhine, with an index above 53 : as in Australians, Negroes, Kaffirs, Zulus, etc.

The form of the orbit varies considerably in different races, but is of much less value from the standpoint of classification. The **orbital index** expresses the proportion of the orbital height to the orbital width, and is obtained by the following formula :—

$$\frac{\text{Orbital height} \times 100}{\text{Orbital width}} = \textbf{Orbital index.}$$

The orbital height is the distance between the upper and lower margins of the orbit at the middle; whilst the orbital width is measured from a point where the ridge which forms the posterior boundary of the lachrymal groove meets the fronto-lachrymal suture (Flower), or from the dacryon (Broca) to the most distant point from these on the anterior edge of the outer border of the orbit.

The form of the orbital aperture is referred to as—
Megaseme, if the index be over 89 ;
Mesoseme, if the index be between 89 and 84 ;
Microseme, if the index be below 84.

The variations met with in the form of the palate and dentary arcade may be expressed by the **palato-maxillary index** of Flower. The length is measured from the alveolar point to a line drawn across the hinder borders of the superior maxillary bones, whilst the width is taken between the outer borders of the alveolar arch immediately above the middle of the second molar tooth. To obtain the index, the following formula is employed :—

$$\frac{\text{Palato-maxillary width} \times 100}{\text{Palato-maxillary length}} = \textbf{Palato-maxillary index.}$$

For purposes of classification Turner has introduced the following terms :—

Dolichuranic, index below 110.
Mesuranic, index between 110 and 115.
Brachyuranic, index above 115.

As has been elsewhere stated (p. 178), the size of the teeth has an important influence on the architecture of the skull. Considered from a racial standpoint, the relative size of the teeth to

the length of the cranio-facial axis has been found by Flower to be a character of much value. The dental length is taken by measuring the distance beween the anterior surface of the first premolar and the posterior surface of the third molar of the upper jaw.

To obtain the **dental index** the following formula is used :—

$$\frac{\text{Dental length} \times 100}{\text{Basinasal length}} = \textbf{Dental index.}$$

Following the convenient method of division adopted with other indices, the dental indices may be divided into three series, called respectively—

Microdont, index below 42 : including the so-called Caucasian or white races.
Mesodont, index between 42 and 44 : including the Mongolian or yellow races.
Megadont, index above 44 : comprising the black races, including the Australians.

Many complicated instruments have been devised to take the various measurements required, but for all practical purposes the calipers designed by Flower or the *compas glissière* of Broca are sufficient.

As an aid to calculating the indices, the tables published in the *Osteological Catalogue of the Royal College of Surgeons of England*, Part I., Man., or the index calculator invented by Dr. Waterston will be found of much service in saving time.

DEVELOPMENT OF THE CHONDRO-CRANIUM AND MORPHOLOGY OF THE SKULL.

As has been already stated (p. 23), the chorda dorsalis extends forwards to a point immediately beneath the anterior end of the mid-brain. In front of this the head takes a bend so that the large fore-brain overlaps the anterior extremity of the notochord. At this stage of development the cerebral vesicles are enclosed in a membranous covering derived from the mesenchyme surrounding the notochord ; this differentiated mesodermal layer is called the primordial membranous cranium. From this the meninges which invest the brain are derived. In lower vertebrates this membranous capsule becomes converted into a thick-walled cartilaginous envelope, the primordial cartilaginous cranium. In mammals, however, only the basal part of this capsule becomes chondrified, the roof and part of the sides remaining membranous. In considering the chondrification of the skull in mammals, it must be noted that part only of the base is traversed by the notochord. It is, therefore, conveniently divided into two parts—one posterior, surrounding the notochord, and hence called **chordal**, and one in front, into which the notochord does not extend, and hence termed **prechordal**. These correspond respectively to the vertebral and evertebral regions of Gegenbauer. In the chordal region a pair of elongated cartilages, called the **parachordal cartilages**, appear one on either side of the notochord ; these soon envelop the chorda, and expand so as to form the basilar or occipital plate, which ossifies later to form the basilar process of the occipital bone, and the dorsum sellæ of the sphenoid. In the prechordal region two curved strips of cartilage, the **trabeculæ cranii** of Rathke, arise and pass forwards from the anterior extremity of the notochord, one on either side of the cranio-pharyngeal canal. In front these trabeculæ spread out and ultimately fuse to form the **ethmoidal plate**, which constitutes the fore part of the chondro-cranium. Posteriorly the trabeculæ unite with the basilar plate and thus surround the cranio-pharyngeal canal, the lumen of which is subsequently closed to form the floor of the pituitary fossa, in which rests the hypophysis cerebri. Owing to the presence of the nasal capsules, the fore part of the ethmoidal plate becomes differentiated into an **ethmo-vomerine region**, from which the nasal septum and its associated cartilages are derived, whilst the remainder of the ethmoidal plate by expansion and subsequent ossification develops to form the presphenoid, the orbito-sphenoids, and the alisphenoids, which latter assist in completing the orbital cavity for the lodgment of the eyeball. The membranous ear capsules which lie lateral to the parachordal cartilages become chondrified and form the **cartilaginous ear capsules**. These soon unite with the lateral aspects of the basilar plate, but are separated in front from the cartilaginous alisphenoid of the ethmoidal plate by a membranous interval, which is subsequently occupied by the squamosal, a bone of dermic origin. This disappearance of the cartilage under the squamosal was regarded by Parker as the diagnostic mark of the mammalian chondro-cranium.

From the ventral surface of this cartilaginous platform—formed, as described, by the union of the trabeculæ, parachordal cartilages, and cartilaginous ear capsules—is suspended the cartilaginous framework of the visceral arches, which play so important a part in the development of the face, an account of which is elsewhere given (p. 36).

A consideration of the facts of comparative anatomy and embryology appears to justify

the assumption that the mammalian skull is of two-fold origin—that, in fact, it is composed of two envelopes, an outer and an inner, primarily distinct, but which in the process of evolution have become intimately fused together. The inner, called the primordial skull, is that which has just been described, and consists of the chondro-cranium and the branchial skeleton. The outer, which is of dermic origin, includes the bones of the cranial vault and face which are developed in membrane. This secondary skull, which first appears in higher fishes as ossified dermal plates overlying the primary skull, acquires a great importance in the mammalia, as owing to the expansion of the brain and the progressive reduction of the chondro-cranium, these dermal bones become engrafted on and incorporated with the primordial skull, and act as covering bones to the cavities of the cranium and face; for it may be well to point out that these dermal or membrane bones are not necessarily external in position, as over the cranial vault, but also develop in the tissues underlying the mucous membrane of the cavities of the face.

Advantage is taken of this difference in the mode of development of the bones of the skull to classify them according to their origin into **cartilage** or **primordial bones**, and **membrane** or **secondary bones.** These differences in the growth of the bone must not be too much insisted on in determining the homologies of the bones of the skull, as it is now generally recognised that all bone is of membranous origin, and that whilst in some cases cartilage may become calcified, it never undergoes conversion into true bone, but is replaced by ossific deposit derived from a membranous source. In the subsequent growth of the skull parts of the cartilaginous cranium persist as the septal and alar cartilages of the nose, whilst for a considerable period the basisphenoid and basioccipital are still united by cartilage.

Till two years after birth there are membranous intervals between the edges and angles of the bones of the cranial vault. These are termed the **fontanelles.** Normally they are six in number, and correspond in the adult to the position of the bregma and lambda in the middle line and the pterion and asterion on either side. The **anterior** or **bregmatic fontanelle** is diamond-shaped, and corresponds to the converging angles of the parietals and two halves of the frontal bone. The **posterior fontanelle** is triangular in form, and lies between the two parietals and the summit of the occipital squama. The **antero-lateral fontanelle** lies between the contiguous margins of the frontal, parietal, squamous temporal, and great wing of the sphenoid, whilst the **postero-lateral fontanelle** is situated between the adjacent borders of the parietal, occipital, and mastoid portion of the temporal.

Whilst in many instances the primordial and secondary bones remain distinct in the fully-developed condition, they sometimes fuse to form complex bones, such as the temporal and sphenoid (see pp. 116 and 123).

Various theories have been advanced to account for the mode of formation of the skull. The earliest of these was called the vertebrate theory, which assumed that the cranium was built up of a series of modified vertebræ, the centra of which corresponded to the basicranial axis, whilst the neural arches were represented by the covering bones of the cranium. In view of the more recent researches regarding the composite origin of the skull above referred to, this theory was necessarily abandoned. It gave way to the suggestion of Gegenbauer that the primordial cranium has arisen by the fusion of several segments equivalent to vertebræ, the number of which he determined by noting the metameric arrangement of the cranial nerves, of which he concluded there were nine pairs, arranged much like spinal nerves, both as to their origin and distribution. The olfactory and optic nerves, though frequently referred to as cranial nerves, are excluded, since from the nature of their development they are to be regarded as metamorphosed parts of the brain itself. Gegenbauer therefore assumed that that portion of the cranial base which is traversed by the nine pairs of segmentally arranged cranial nerves must be formed by the fusion of nine vertebral segments; and as the region where the nerves escape corresponds to the part of the chondro-cranium traversed by the notochord, he calls it the vertebral portion of the cranial base, in contradistinction to the trabecular or non-vertebral part which lies in front. This latter he regards as a new formation adapted to receive the greatly-developed brain and afford protection to the organs of sight and smell.

As has been pointed out by Hertwig, there is an essential difference between the development of the axial cartilaginous skeleton of the trunk and head. The former becomes segmented into distinct vertebræ alternating with intervertebral ligaments; whilst the latter, in order to attain the rigidity necessary in this part of the skeleton, is never so divided. It follows from this that the original segmentation of the head is only expressed in three ways, viz. in the appearance of several primitive segments (myotomes), in the arrangement of the cranial nerves, and in the fundament of the visceral skeleton (visceral

arches). According to Froriep the mammalian occipital corresponds to the fusion of four vertebræ, and there is some reason for supposing that in some classes of vertebrates the occipital region of the primordial cranium is increased by fusion with the higher cervical segments.

The form of skull characteristic of man is dependent on the large proportionate development of the cranial part, which contains the brain, and the reduction in size of the visceral part (face), which protects the organs of special sense. This leads to a decrease in the size and projection of the jaws, as well as a reduction in the size of the teeth. Associated with the smaller mandible there is a feebler musculature, with a reduced area of attachment to the sides of the skull. In this way the disappearance of the muscular crests and fossæ, so characteristic of lower forms, is accounted for. At the same time the fact that the skull is poised on the summit of a vertical column, leads to important modifications in its structure. The disposition of parts is such that the occipito-vertebral articulation is so placed that the fore and hind parts of the head nearly balance each other, thus obviating the necessity for a powerful muscular and ligamentous mechanism to hold the head erect.

Another noticeable feature in connexion with man's skeleton is the prolonged period during which growth may occur before maturity is reached; this is associated with a more complete consolidation of the skull, since bones, which in lower forms remain throughout life distinct, are in man fused with each other, as exemplified in the case of the presphenoid and postsphenoid, the occipital and the interparietal, to mention one or two instances among many. It is noteworthy, however, that during ontogeny the morphological significance of these bones is clearly demonstrated by their independent ossification.

The points of exit of the various cranial nerves remain remarkably constant, and in their primitive condition serve to suggest the segmental arrangement of the cartilaginous chondro-cranium already referred to. Owing to the very great modifications which the mammalian skull has undergone in the process of its evolution, it may be pointed out that the passage of the nerves through the dura mater—a derivative, the readers may be reminded, of the primordial membranous cranium (see *ante*)—alone represents the primitive disposition of the nerves. Their subsequent escape through the bony base is a later and secondary development. In some cases the two, membranous or primary and the osseous or secondary foramina, correspond. In other instances the exit of the nerves through the dura mater does not coincide with the passage through the bone.

Of interest in this connexion it may be pointed out that the foramina and canals which traverse the skull are either situated in the line of suture between adjacent bones or in the line of fusion of the constituent parts of which the bone pierced is made up. For example, the sphenoidal fissure is situated between the orbito and alisphenoids; the anterior condylic between the basi and exoccipitals; the jugular between the petrous, basi, and exoccipital; the optic between the orbito-sphenoid and the presphenoid; the Vidian between the alisphenoid, internal pterygoid plate, and the lingula.

THE BONES OF THE UPPER EXTREMITY.

The Clavicle.

The **clavicle** (clavicula), or collar bone, one of the elements in the formation of the shoulder girdle, consists of a curved shaft, the extremities of which are

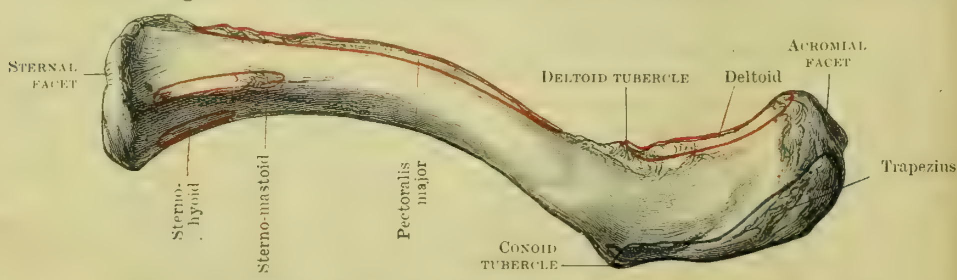


Fig. 122.—Right Clavicle as seen from Above.

enlarged. The inner end, since it articulates with the sternum, is called the sternal end; the outer extremity, from its union with the acromion process of the scapula, is known as the acromial end.

The **sternal end** (extremitas sternalis) is enlarged, and rests upon the meniscus of fibro-cartilage which is interposed between it and the clavicular facet on the upper and external angle of the manubrium sterni, as well as a small part of the inner end of the cartilage of the first rib. Its *articular surface*, usually broader

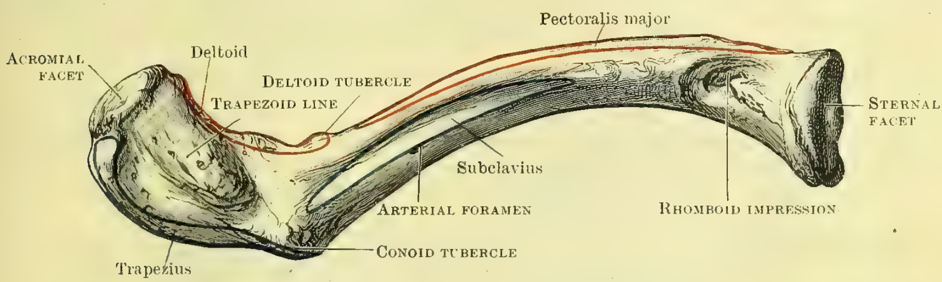


FIG. 123.—RIGHT CLAVICLE AS SEEN FROM BELOW.

from above downwards than from side to side, displays an antero-posterior convexity, whilst it tends to be slightly concave in a vertical direction. The edge around the articular area which serves for the attachment of the capsule of the sterno-clavicular articulation is sharp and well defined, except below where it is rounded.

The **shaft** is so curved that its anterior outline is convex in its inner two-thirds, whilst concave in the outer third of its length. Rounded or prismatic in form towards its sternal extremity, it becomes compressed and flattened towards its outer end. The *superior surface* of the shaft, which is smooth and subcutaneous throughout its whole length, is directed upwards and forwards; the *inferior surface* is inclined downwards and backwards. The *anterior border*, which separates the upper from the under surface in front, is rough and tubercular towards its inner end for the attachment of the clavicular fibres of the pectoralis major, whilst externally, where it becomes continuous with the anterior margin of the acromial end, it is better defined, and bears the imprint of the origin of the fibres of the deltoid muscle; here, not uncommonly, a projecting spur of bone, called the **deltoid tubercle**, may be seen. The *posterior border* is broad internally, where it is lipped superiorly to furnish an attachment for the clavicular fibres of the sterno-mastoid muscle; behind and below this the sterno-hyoid and sterno-thyroid muscles are attached to the bone. Externally, the posterior border becomes more rounded, and is confluent with the posterior edge of the acromial end at a point where there is a marked outgrowth of bone from its under surface, **the conoid tubercle** (tuberositas coracoidea). Into the outer third of this border are inserted the upper and anterior fibres of the trapezius muscle. The *inferior surface* of the shaft close to the sternal end is marked by an irregular elongated impression (tuberositas costalis), often deeply pitted for the attachment of the rhomboid ligament, which unites it to the cartilage of the first rib. External to this the shaft is channelled by a groove which terminates close to the conoid tubercle; into this groove the subclavius muscle is inserted.

The **acromial end** of the bone is flattened and compressed from above downwards, and expanded from before backwards; its anterior edge is sharp and well defined, and gives attachment to the deltoid muscle, which also spreads over part of its upper surface. Its posterior margin is rougher and more tubercular, and provides a surface for the insertion of the trapezius. The area between these two muscular attachments is smooth and subcutaneous. The outer edge of this forward-turned part of the bone is provided with an oval facet (facies articularis acromialis) for articulation with the acromion process of the scapula; the margins around this articular area serve for the attachment of the capsule of the joint. The inferior surface of the acromial end of the bone is traversed obliquely from behind forwards and outwards by a rough ridge or line called the **trapezoid** or **oblique ridge.** The posterior extremity of this ridge, as it abuts on the posterior border of the bone, forms a prominent process, the **conoid tubercle** (tuberositas coracoidea); to each of these, respectively, are attached the trapezoid and conoid portions of the coraco-clavicular ligament.

Nutrient Foramina.—The foramina for the larger nutrient vessels, of which there may be one or two directed outwards, are usually found about the middle of the posterior border, or it may be opening into the floor of the groove for the subclavius muscle.

Architecture.—The shaft consists of an outer layer of compact bone, thickest towards the centre, but gradually thinning towards the extremities, the investing envelope of which consists merely of a thin shell. Within the shaft the cancellous tissue displays a longitudinal striation, which internally assumes a more cellular appearance. At the acromial end the general arrangement of the fibres resembles the appearance of the sides of a Gothic arch.

Variations.—The clavicles of women are more slender, less curved, and shorter than those of men. In the latter the bone is so inclined that its outer end lies slightly higher or on the same level with the sternal end. In women the bone usually slopes a little downward and outward. The more pronounced curves of some bones are associated with a more powerful development of the pectoral and deltoid muscles, a circumstance which also affords an explanation of the differences usually seen between the right and left bones, the habitual use of the right upper limb reacting on the form of the bone of that side.

Ossification.—Phylogenetically of dermic origin, the clavicle in man is remarkable in commencing to ossify before any other bone in the body; this occurs as early as the fifth or sixth week of fœtal life. The **primitive centre** from which the shaft and outer extremity are developed appears prior to the formation of any cartilaginous matrix; and it is not till a later stage that cartilage plays a part in the development of the bone by assisting in the growth of its extremities.

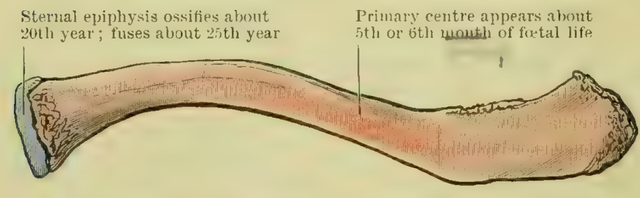


FIG. 124.—OSSIFICATION OF THE CLAVICLE.

A **secondary centre** or **epiphysis** appears at the sternal end about the age of twenty or later, and fusion rapidly occurring between it and the shaft, ossification is completed at the age of twenty-five or thereabouts.

THE SCAPULA.

The **scapula** (scapula), shoulder blade or blade bone, is of triangular shape and flattened form. It has two surfaces, ventral and dorsal. From the latter there springs a triangular process called the spine, which ends externally in the acromion; whilst from its superior border there arises a beak-like projection called the coracoid process.

The **body** of the bone, which is thin and translucent, except along its margins and where the spine springs from it, has three borders and three angles. Of these borders the *internal* or *vertebral* (margo vertebralis) is the longest; it stretches from the superior angle above to the inferior angle below. Of curved or somewhat irregular outline, it affords a narrow surface for the insertion of the levator anguli scapulæ, rhomboideus minor, and rhomboideus major muscles.

The *superior border* (margo superior), which is thin and sharp, is the shortest of the three. It runs from the superior angle towards the root of the coracoid process, before reaching which, however, it is interrupted by the **suprascapular notch** (incisura scapulæ), which lies immediately to the inner side of the base of that process. This notch, which is converted into a foramen by a ligament, or occasionally by a spicule of bone, transmits the suprascapular nerve. Attached to the superior border, close to the notch, is the posterior belly of the omo-hyoid. The *external* or *axillary border* (margo axillaris), so called from its relation to the hollow of the armpit (axilla), is much stouter than either of the others; it extends from the external angle above to the inferior angle below. The upper inch or so of this border, which lies immediately below the glenoid articular surface, is rough and tubercular (tuberositas infraglenoidalis), and affords attachment to the long head of the triceps. Below this there is usually a groove which marks the position of the dorsal artery of the scapula. The *superior angle* (angulus medialis) is sharp and more or less rectangular; the *inferior angle* (angulus inferior) is blunter and more acute; whilst the *external angle* (angulus lateralis) corresponds to that part of the bone which is sometimes called the **head**, and which supports the **glenoid surface** and the **coracoid prceoss.**

The **glenoid surface** is a pyriform articular area, slightly concave from above downwards and from side to side; its border is but slightly raised above the general surface and affords attachment in the recent condition to the glenoid ligament, which helps to deepen the socket in which the head of the humerus rests. Below, this edge is confluent with the **infraglenoid impression** (tuberositas infraglenoidalis), whilst above it blends with a tubercle (tuberositas supraglenoidalis), to which the long head

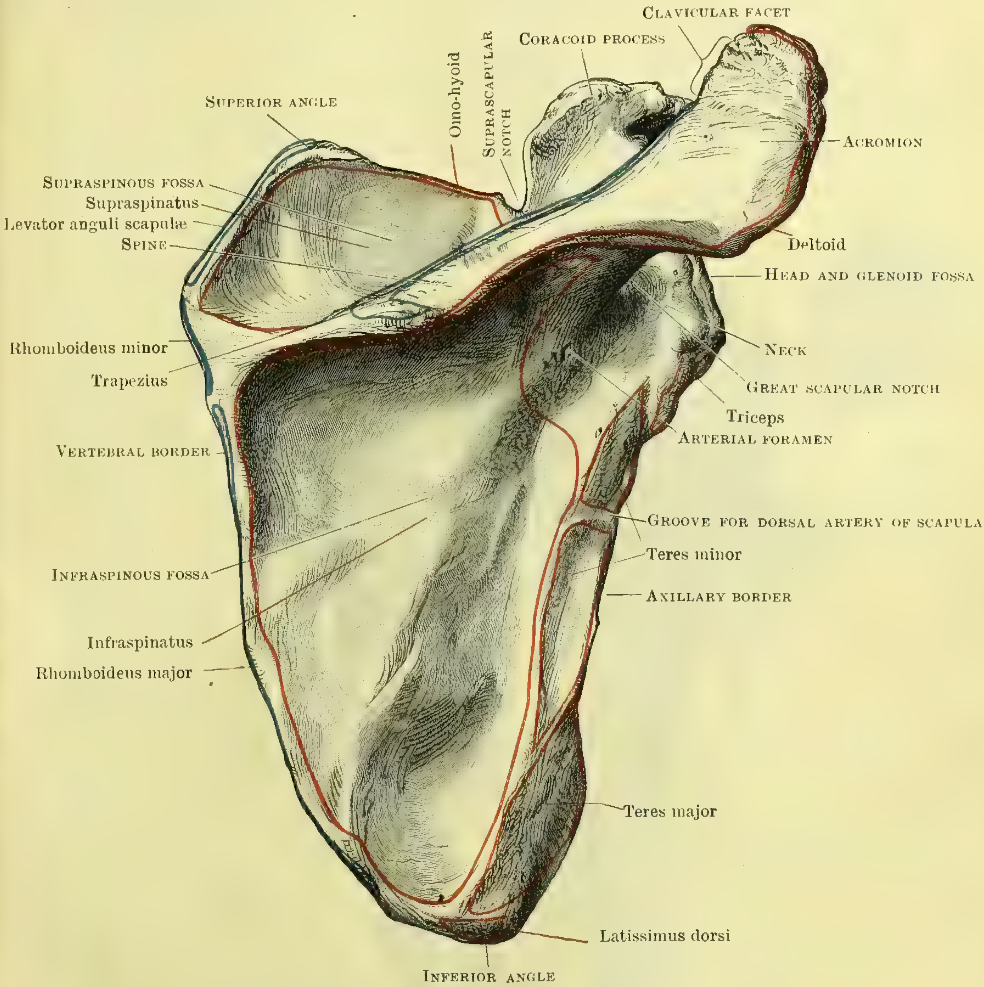


Fig. 125.—The Right Scapula as seen from Behind.

of the biceps muscle is attached. Springing from the upper part of the head, in line with the superior border, is the **coracoid process** (processus coracoideus). The base of this is limited externally by the glenoid edge, whilst internally it is separated from the superior border by the suprascapular notch. Rising upwards for a short space, it bends on itself at nearly a right angle, and ends in a process which is directed outwards and slightly forwards, overhanging the glenoid fossa above and in front. Compressed from above downwards, it has attached to its upper surface near its angle the conoid ligament, wide of which there is a rough area for the trapezoid ligament. Attached to its posterior border is the coraco-acromial ligament, whilst at its extremity and towards the front part of its anterior border, is the combined origin of the biceps and coraco-brachialis, together with the insertion of the pectoralis minor. The **neck** (collum scapulæ) is that somewhat constricted part of the bone which supports the head; it corresponds in front and behind to a line drawn from the suprascapular notch to the infraglenoid tubercle.

The body of the bone has two surfaces, a **dorsal** (facies dorsalis) and a **ventral** (facies costalis). The former is divided into two fossæ by an outstanding process of triangular form, called the **spine** (spina scapulæ). The attached border of this

crosses the back of the body obliquely in a direction outwards and slightly upwards, extending from the vertebral border near the lower limit of its upper fourth towards the centre of the posterior glenoid edge, from which, however, it is separated by the **great scapular notch,** which here corresponds to the posterior aspect of the neck. The surfaces of the spine, which are directed upwards and downwards, are concave, the upper entering into the formation of the **supraspinous fossa**, which lies above it, the lower forming the upper wall of the **infraspinous fossa,** which lies below it. The two fossæ are in communication with each other round the free external concave border of the spine, where that curves over the great scapular notch. The posterior free border of the spine is subcutaneous throughout its entire length. Its upper and lower edges are strongly lipped, and serve—the superior, for the attachment of the trapezius; the inferior, for the origin of the deltoid. The intervening surface varies in width—broad and triangular where it becomes confluent with the vertebral border, it displays a smooth surface, over which the tendinous fibres of the trapezius play; narrowing rapidly, it forms a surface of varying width which blends externally with a flattened process, the two forming a compressed plate of bone which arches across the scapular notch above and behind, and then curves forwards, upwards, and outwards to overhang the glenoid fossa. The internal border of this process is continuous with the upper margin of the spine, and is gently curved. The external border, more curved than the inner, with which it is united in front, is confluent with the inferior edge of the spine, with which it forms an abrupt bend, termed the **acromial angle.**

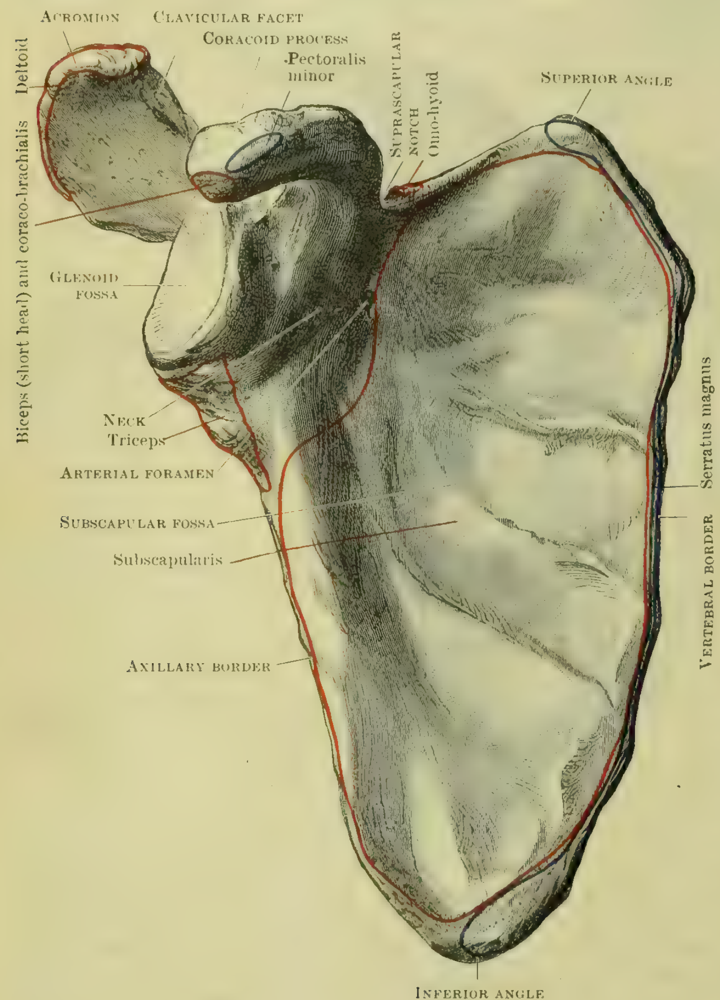


Fig. 126.—The Right Scapula as seen from the Front.

The bone included between these two borders is called the **acromion process.** Of compressed form, it much resembles the acromial end of the clavicle, with which it articulates by means of a facet (facies articularis acromii) which is placed on its internal border near its anterior extremity. The superior surface of the acromion, which is broad and expanded, is subcutaneous, and is directed upwards and backwards, and in the normal position of the bone outwards as well. Its internal edge, where not in contact with the clavicle, has attached to it the fibres of the trapezius, whilst its external margin affords origin to the central part of the deltoid. At its anterior extremity it is connected with the coracoid process by

means of the coraco-acromial ligament. Its under surface is smooth and overhangs the shoulder joint.

The **supraspinous fossa**, of much less extent than the infraspinous, is placed above the spine, the upper surface of which assists in forming its curved floor; in it is lodged the supraspinatus muscle. The suprascapular notch opens into it above, whilst below and externally it communicates with the infraspinous fossa by the great scapular notch, through which the suprascapular artery and nerve pass to reach the infraspinous fossa.

The **infraspinous fossa**, overhung by the spine above, is of triangular form. The axillary border of the bone limits it in front, whilst the vertebral margin bounds it behind; the greater part of this surface affords origin to the infraspinatus muscle, excepting a well-defined area which skirts the axillary border and inferior angle of the bone, and which affords an attachment to the fibres of origin of the teres minor. This muscle extends along the posterior surface of the axillary border in its upper two-thirds, reaching nearly as high as the glenoid edge; whilst a crescentic surface, which occupies the lower third of the axillary border and curves backward round the posterior aspect of the inferior angle, furnishes an origin for the teres major muscle. Here also, near the inferior angle, are occasionally attached some of the fibres of the latissimus dorsi muscle.

The **ventral aspect** (facies costalis) of the body is hollow from above downwards and from side to side, the greatest depth being in correspondence with the spring of the spine from the dorsal surface. Its inner boundary, which is formed by the anterior lipped edge of the vertebral border, affords attachment to the fibres of insertion of the serratus magnus along the greater part of its extent. The area of insertion of this muscle is, however, considerably increased over the anterior aspects of the superior and inferior angles respectively. Running down from the head and neck above to the inferior angle below, there is a stout rounded ridge of bone, which imparts a fulness to the anterior aspect of the axillary border and increases the depth of the ventral hollow; to this, as well as to the floor of the fossa, the subscapularis muscle is attached. The tendinous intersections of this muscle leave their imprint on this surface of the bone in a series of three or four rough lines which converge towards the neck.

Nutrient Foramina.—Foramina for the passage of nutrient vessels are seen in different parts of the bone; the most constant in position is one which opens into the infraspinous fossa, about an inch or so from the scapular notch. Others are met with on the upper and under surfaces of the spine, on the ventral aspect near its deepest part, and also around the glenoid margin.

Connexions.—The scapula is not directly connected with the trunk, but articulates with the outer end of the clavicle, in union with which it forms the shoulder girdle supporting the humerus on its glenoid surface. Placed on the upper and back part of the thorax, it covers the ribs from the second to the seventh inclusive. Possessed of a wide range of movement, it alters its position according to the attitude of the limb, rising or falling, being drawn inwards or outwards, or being rotated upon itself according as the arm is moved in various directions. These changes in position can easily be determined by recognising the altered relations of the subcutaneous and bony prominences, more especially the former, which include the spine, the acromion process, and the lower half of the vertebral border.

Architecture.—For so light and thin a bone, the scapula possesses a remarkable rigidity. This is owing to the arrangement of its parts. Stout and thick where it supports the glenoid surface and coracoid process, the rest of the bone is thin, except along the axillary border; but strength is imparted to the body by the manner in which the spine is fused at right angles to its posterior surface.

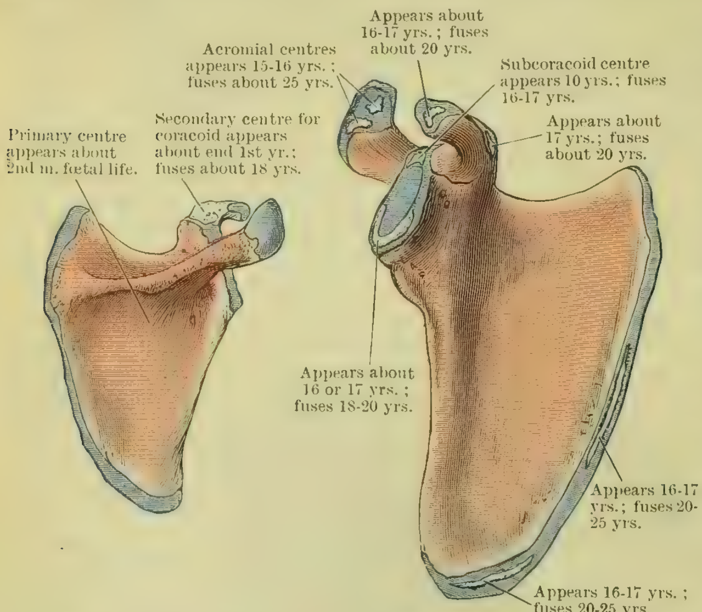
Variations.—The most common variation met with is a separated acromion process. In these cases there has been failure in the ossific union between the spine and acromion, the junction between the two being effected by a layer of cartilage or an articulation possessing a joint cavity. The condition is usually symmetrical on both sides, though instances are recorded where this arrangement is unilateral. Very much rarer is the condition in which the coracoid process is separable from the rest of the bone. The size and form of the suprascapular notch differs. In certain cases the superior border of the bone describes a uniform curve reaching the base of the coracoid without any indication of a notch. In some scapulæ, more particularly in those of very old people, the floor of the subscapular fossa is deficient owing to the absorption of the thin bone, the periosteal layers alone filling up the gap.

At birth the vertical length of the bone is less in proportion to its width than in the adult.

Ossification.—Ossification begins in the body of the cartilaginous scapula about the end of the second month of fœtal life. At birth the head, neck, body, spine, and base of the coracoid process are well defined; the vertebral border, inferior angle, glenoid fossa, acromion and coracoid processes, are still cartilaginous. The centre for the upper and

fore part of the coracoid appears in the first year, and fusion along an oblique line leading from the upper edge of the glenoid fossa to the conoid tubercle is complete about the fifteenth year. A separate centre (subcoracoid), which ultimately includes the upper part of the glenoid fossa and external part of the coracoid process, makes its appearance about the tenth year, and fuses with the surrounding bone about sixteen or seventeen. Up till the age of puberty the acromion remains cartilaginous; centres, two or more in number, then make their appearance, which coalesce and ultimately unite with the spine about the twenty-fifth year. Failure of union may, however, persist throughout life (see *ante*, Variations).

Ossification commences in the cartilage in the inferior angle about puberty, and independently and a little later, along the vertebral margin, fusion with the body occurring at from twenty to twenty-five years.



Scapula at end of First Year. Scapula about the Age of Puberty.

FIG. 127.—OSSIFICATION OF THE SCAPULA.

Small scale-like epiphyses make their appearance on the upper surface and at the extremity of the coracoid, and are completed about the twentieth year. A thin epiphysial plate develops over the lower part of the glenoid fossa about sixteen or seventeen, fusion being complete about eighteen or twenty years of age.

THE HUMERUS.

The **humerus**, or bone of the upper arm, articulates with the scapula above and with the bones of the forearm, the radius and ulna, below. Its upper end comprises the **head** and **great** and **small tuberosities**; its **shaft**, which is longer than any of the other bones of the upper extremity, is cylindrical above and flattened below, where it ends in the inferior extremity, which is expanded to form the **condyles** on either side, and supports the **trochlear** and **capitellar** articular surfaces for the ulna and radius respectively.

The **superior extremity** is the thickest and stoutest part of the bone. The **head** (caput humeri), which forms about one-third of a spheroid and is covered by articular cartilage, is directed upwards, inwards, and slightly backwards, and rests in the glenoid fossa of the scapula; the convexity of its surface is most pronounced in its posterior half. Separating the head from the tuberosities externally is a shallow groove, which fades away on the surface of the bone which supports the articular surface inferiorly. This is named the **anatomical neck** (collum anatomicum) and serves for the attachment of the capsule of the shoulder joint. The articular edge of the groove opposite the small tuberosity is usually notched for the attachment of the superior gleno-humeral ligament. The **great tuberosity** (tuberculum majus) abuts on the outer side of the head and becomes continuous with the shaft below. Its upper surface forms a quadrant, which is subdivided into three more or less smooth areas of unequal size. Of these the highest and anterior is for the insertion of the supraspinatus muscle, the middle for the infraspinatus, whilst the lowest and posterior serves for the insertion of the teres minor muscle. The outer surface of this tuberosity, which bulges beyond the line of the shaft, is rough and pierced by numerous foramina. Anteriorly the great tuberosity is separated from the **small**

tuberosity (tuberculum minus) by a well-defined furrow, called the **bicipital groove** (sulcus intertubercularis), from the circumstance that the tendon of origin of the long head of the biceps muscle is lodged within it. The **small tuberosity** lies in front of the outer half of the head; it forms a pronounced elevation, which fades into the shaft below. The surface of this tuberosity is faceted above and in front for the insertion of the subscapularis muscle, whilst externally it forms the prominent inner lip of the bicipital groove. Below the head and tuberosities the shaft of the bone rapidly contracts, and is here named the **surgical neck** (collum chirurgicum) owing to its liability to fracture at this spot.

The **shaft**, or body (corpus humeri), is cylindrical in its upper half. On it the **bicipital groove** may be traced downwards and slightly inwards, along its anterior surface. The edges of the groove, which are termed its lips, are confluent above with the great and small tuberosities respectively. Here they are prominent, and form the crests of the great and small tuberosities (cristæ tuberculi majoris et minoris). Inferiorly the lips of the bicipital groove gradually fade away, the inner more rapidly than the outer, which latter may usually be traced down to a rough elevation placed on the outer side of the shaft about its middle, called the **deltoid eminence**. Into the outer lip of the bicipital groove are inserted the fibres of the pectoralis major muscle; hence it is sometimes described as the pectoral ridge. To the floor of the groove the latissimus dorsi is attached; whilst the teres major muscle is inserted into the inner lip.

The **deltoid eminence** (tuberositas deltoidea), to which the powerful deltoid muscle is attached, is a rough, slightly elevated V-shaped surface, placed on the outer side of the shaft about its middle. The anterior limb of the V is parallel to the axis of the shaft, and is continuous with the outer lip of the bicipital groove above, whilst the

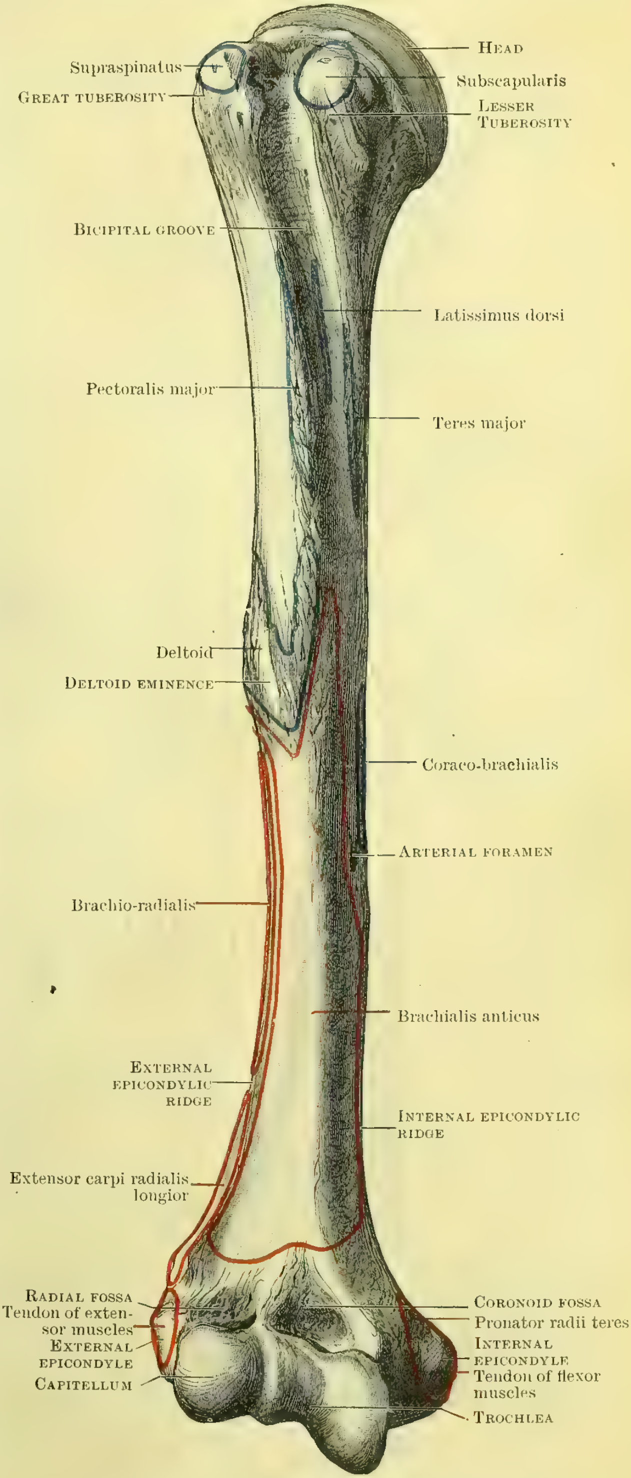


Fig. 128.—Anterior View of the Right Humerus.

posterior limb of the V winds obliquely round the outer side of the bone towards the posterior surface, where it becomes continuous with a slightly elevated and occasionally rough ridge which leads up the back of the bone towards the great tuberosity superiorly; from this latter ridge the outer head of the triceps muscle arises.

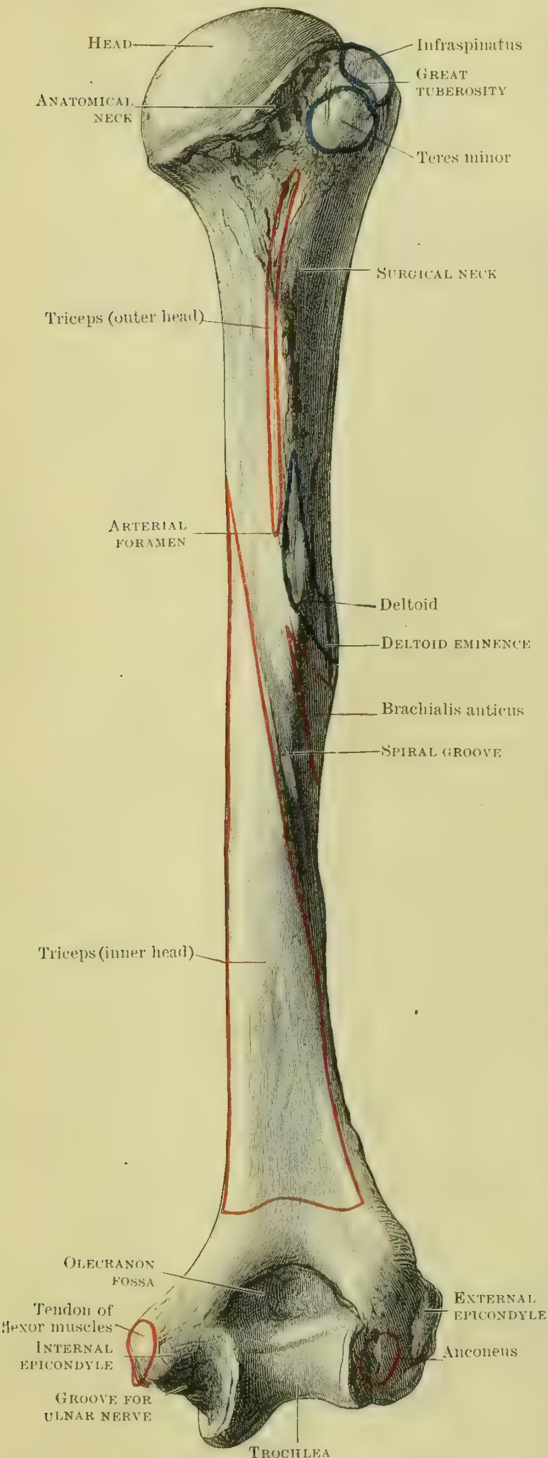


Fig. 129.—Posterior View of the Right Humerus.

The inner surface of the shaft about its middle inclines to form a rounded border, on which there is often a rough linear impression, which marks the insertion of the coraco-brachialis muscle. Below this the shaft becomes compressed and expanded laterally, ending inferiorly on either side in the **condyles.** Its surfaces are now anterior and posterior, being separated from each other by two clearly defined borders, the **epicondylic ridges.** Of these, the internal, **margo medialis**, is the more curved and less prominent, and is continuous above with the surface to which the coraco-brachialis is attached, whilst inferiorly it ends by blending with the internal condyle. The external epicondylic ridge, **margo lateralis**, is straighter and more projecting; its edge is usually distinctly lipped. Confluent with the external condyle inferiorly, it may be traced upwards to near the deltoid eminence, where it turns backwards more or less parallel to the posterior oblique border of that impression, to be lost on the posterior surface of the shaft. The interval between this border and the deltoid eminence is thus converted into a shallow oblique furrow, which winds round the outer surface of the bone just below its middle; this constitutes the **musculo-spiral groove** (sulcus radialis) along which the musculo-spiral nerve, together with the superior profunda artery, passes from the back to reach the front of the arm. To the epicondylic ridges are attached the intermuscular septa, whilst the external in its upper two-thirds furnishes a surface for the origin of the brachio-radialis (supinator longus), and in its lower third for the extensor carpi radialis longior muscle.

The anterior surface of the lower half of the shaft is of elongated triangular form, the base corresponding to the inferior extremity of the bone. Running down the centre of this is a broad,

rounded, elevated ridge, most pronounced above, where it joins the deltoid eminence, and sloping on either side towards the epicondylic ridges; it is into the outer of these slopes that the musculo-spiral groove flows. Inferiorly the elevated surface spreads out, and becomes confluent with the condyles, more correctly termed the epicondyles. The **internal epicondyle** (epicondylus medialis) is the more prominent of the two, and furnishes a surface for the origin of the pronator radii teres, and the superficial flexor muscles of the forearm. The **external epicondyle** (epicondylus lateralis), stunted and but little projecting, serves for the attachment of the common tendon of origin of the extensor muscles. The brachialis anticus muscle has an extensive origin from the anterior surface of the lower half of the shaft, including between its upper slips the insertion of the deltoid.

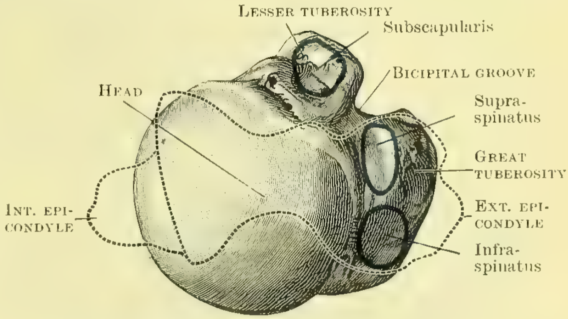


Fig. 130.—The Head of the Right Humerus as seen from Above (with the outline of the lower extremity in relation thereto shown in dotted line.)

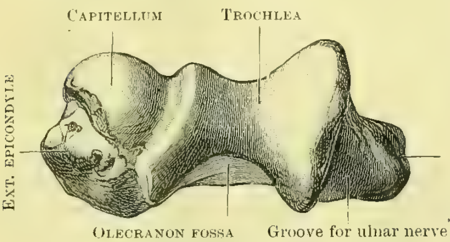


Fig. 131.—The Lower Extremity of the Right Humerus as seen from Below.

The posterior surface of the lower half of the shaft is smooth and rounded from side to side; somewhat flattened below, where the whole shaft tends to incline forwards, it becomes continuous on either side with the posterior surfaces of the epicondyles, the inner of which is grooved for the passage of the ulnar nerve, whilst the external supplies an origin for the anconeus muscle. The inner head of the triceps muscle has an extensive origin from the posterior surface of the lower two-thirds of the shaft, internal to and below the musculo-spiral groove.

The **lower extremity** of the humerus is furnished with two articular surfaces (the condyles proper), the outer of which, called the **capitellum** (capitulum), for articulation with the upper surface of the head of the radius, is a rounded eminence, placed on the anterior surface and lower border, but not extending upwards on the posterior surface of the inferior end of the bone. Above it, in front, there is a shallow depression (fossa radialis), into which the margin of the head of the radius sinks when the elbow is strongly flexed. A shallow groove separates the capitellum internally from the **trochlea**, which is a grooved articular surface, with prominent edges winding spirally round the lower extremity of the shaft. The spiral curves from behind forwards and inwards, and its axis is slightly oblique to the long axis of the shaft. The inner lip is the more salient of the two, and forms a sharp and well-defined margin to the articular area; its cartilage-covered surface is slightly convex. The outer lip, much less prominent, is rounded off into the articular groove which separates it from the capitellum, posterior to which, however, it is carried up as a more or less definite crest. It is by means of the trochlea that the

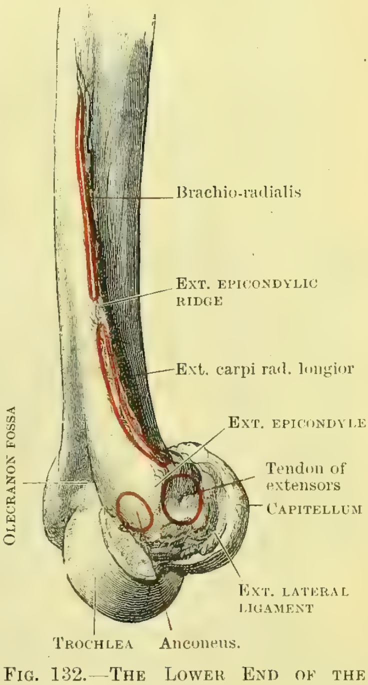


Fig. 132.—The Lower End of the Right Humerus as seen from the Outer Side.

humerus articulates with the great sigmoid cavity of the ulna. On the anterior surface of the bone, immediately above the trochlea, is a depression—the **coronoid fossa** (fossa coronoidea), in which the coronoid process of the ulna rests in flexion of the joint, whilst in a corresponding position on the back of the lower end of the shaft there is a hollow, called the **olecranon fossa** (fossa olecrani), just above the trochlea posteriorly. Into this the olecranon process sinks when the elbow is extended. The two fossæ are separated by a thin translucent layer of bone which may be deficient, thus leading to the formation of a foramen between the two hollows in the macerated bone. The anterior part of the capsule of the elbow joint is attached to the superior margins of the radial and coronoid fossæ in front, whilst the posterior ligament is connected with the upper border and lateral edges of the olecranon fossa behind. The strong internal and external lateral ligaments are attached superiorly to the internal and external epicondyles respectively. The proportionate length of the humerus to the body height is as 1 is to 4·93–5·25.

Nutrient foramina are usually to be seen, one at or near the surface for the insertion of the coraco-brachialis, the other usually close to the hinder border of the deltoid eminence; both have a downward direction. Numerous vascular foramina are scattered along the line of the anatomical neck, the larger ones being situated near the upper end of the bicipital groove.

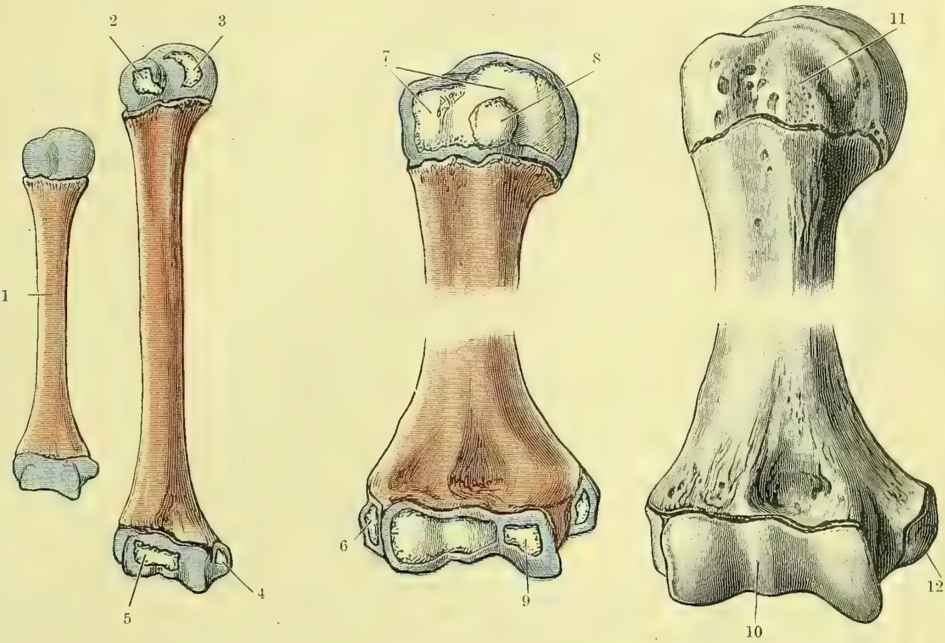
Connexions.—The humerus articulates with the scapula above, and radius and ulna below. Embedded as the humerus is in the substance of the upper arm, its shaft and head are surrounded on all sides. It is only at its lower part that it comes into direct relation with the surface, the internal epicondyle forming a characteristic projection on the inner side of the elbow; whilst the external epicondyle, less prominent, and the external epicondylic ridge can best be recognised when the elbow is bent.

Architecture.—The shaft consists of a layer of compact bone surrounding a long medullary canal. The outer shell, thickest in the lower third of the bone, gradually thins until it reaches the superior epiphysial line, where it forms a layer no thicker than stout paper. Inferiorly the external shell is thicker and stouter than above, until it reaches the epicondyles, below which the articular surfaces are formed of a layer of compact spongy bone. The upper end of the medullary canal is surrounded by loose spongy tissue, the fibres of which arch inwards from the inner surface of the compact outer layer, whilst inferiorly the cancellous tissue which springs from the outer shell sweeps downwards in a radiating fashion on either side of the olecranon fossa towards the epicondyles. Above the olecranon fossa there are a number of laminæ of dense bone which arch across from one side to the other, the convexity of the arches being directed downwards. The superior epiphysis, formed of spongy bone, is united to the shaft by a wavy line, concave externally and convex internally, leading from the base of the great tuberosity on the outer side to the inferior articular edge on the inner side. The mass above this includes the head and two tuberosities. The spongy tissue of the head is fine, and is arranged generally in lines radial to its surface; that of the great tuberosity is more open, and often displays large spaces towards its interior, which in old bones communicate freely with the medullary cavity of the shaft. The general direction of the fibres is parallel to the outer surface of the tuberosity. The lower articular end is formed of fine spongy tissue, more compact towards the surface, and arranged in lines more or less at right angles to its articular planes. In the adult the principal nutrient canal, viz. that which opens on the surface near the insertion of the coraco-brachialis, traverses the outer compact wall of the shaft obliquely downwards for a distance of two and a quarter inches before it opens into the medullary cavity.

Variations.—As has been already stated, the olecranon and coronoid fossæ may communicate with each other in the macerated bone. The resulting supratrochlear foramen is more commonly met with in the lower races of man, as well as in the anthropoid apes, and in some other mammals. The occurrence of a hook-like spine, called the epicondylic process, which projects in front of the internal epicondylic ridge, is not uncommon. Its extremity is connected with the internal epicondyle by means of a fibrous band, underneath which the median nerve, accompanied by the brachial artery, or one of its large branches, may pass, or in some instances, the nerve alone, or the artery unaccompanied by the nerve. This process is the homologue in a rudimentary form of a canal present in many animals, notably in the carnivora and marsupials. In addition to the broad musculo-spiral groove already described, and which is no doubt produced by the twisting or torsion of the shaft, there is occasionally a distinct narrow groove posterior to it, which marks precisely the course of the musculo-spiral nerve as it turns round the outer side of the shaft of the bone.

Ossification.—At birth the shaft of the humerus is usually the only part of the bone ossified, if we except the occasional presence (22 per cent) of an ossific centre in the head. (H. R. Spencer, *Journ. Anat. and Physiol.* vol. xxv. p. 552.) The centre for the **shaft** makes its appearance early in the second month of intrauterine life. Within the first six months after birth a centre usually appears for the **head**; this is succeeded by one for the **great tuberosity** during the second or third year. These soon coalesce; and

a third centre for the **small tuberosity** begins to appear about the end of the third year, or may be delayed till the fourth or fifth year. These three centres are all blended by the seventh year, and form an **epiphysis**, which ultimately unites with the shaft about the age of twenty-five. It may be noticed that the superior end of the diaphysis is conical and pointed in the centre, over which the epiphysis fits as a cap, an arrangement which thus tends to prevent its displacement before union has occurred. The first centre to appear in the *lower extremity* is that for the **capitellum** about the second or third year. This extends inwards, and forms the outer half of the **trochlear surface**, the centre for the inner half not making its appearance till the eleventh or twelfth year.



At birth. About 5 years. About 12 years. About 16 years.

FIG. 133.—OSSIFICATION OF THE HUMERUS.

1. Appears early in 2nd month fœtal life.
2. For tuberosity, appears 2 to 3 years.
3. For head, appears within first 6 months.
4. For internal condyle, appears about 5 years.
5. For capitellum, appears 2 to 3 years.
6. Appears about 12 years.
7. Centres for head and great tuberosity, coalesce about 5 years.
8. Centres for small tuberosity fuse with other centres about 7 years.
9. Appears about 11 or 12 years.
10. Inferior epiphysis fuses with shaft about 16 to 17 years.
11. Superior epiphysis fuses with shaft about 25 years.
12. Fuses with shaft about 17 to 18 years.

Separate centres are developed in connexion with the **epicondyles**; that for the external appears about the twelfth year, and rapidly coalescing with the centres for the capitellum and trochlea forms an **epiphysis**, which unites with the shaft about the sixteenth or seventeenth year. The centre for the **internal epicondyle** appears about the fifth year; it forms a separate **epiphysis**, which unites with the shaft about eighteen or nineteen. These two epiphyses at the lower end of the bone are separated by a down-growth of the shaft, which lies between the internal epicondyle and the trochlea, and forms part of the base and inner side of the latter process.

The epicondylic process when present is developed from the diaphysis, and has been observed to be already well ossified by the third year. ("Proc. Anat. Soc." *Journ. Anat. and Physiol.*, 1898.)

THE ULNA.

Of the two bones of the forearm, the **ulna**, which is placed internally, is the longer. It consists of a large superior extremity supporting the **olecranon** and **coronoid** processes; a shaft tapering from above downwards; and a small rounded inferior end called the **head**.

Superior extremity.—The **olecranon process** (olecranon) lies in line with the shaft. Its posterior surface, more or less triangular in form, is smooth and

subcutaneous and covered by a bursa. Its superior aspect, which forms with the posterior surface a nearly rectangular projection—the tip of the elbow—furnishes a surface for the insertion of the tendon of the triceps muscle, together with a smooth area which is overlain by the same tendon, but separated from it by a bursal sac. To the anterior crescentic border of this process are attached the fibres of the posterior part of the capsule and portion of the internal lateral ligament of the elbow joint. The anterior surface is articular, and enters into the formation of the **great sigmoid cavity**.

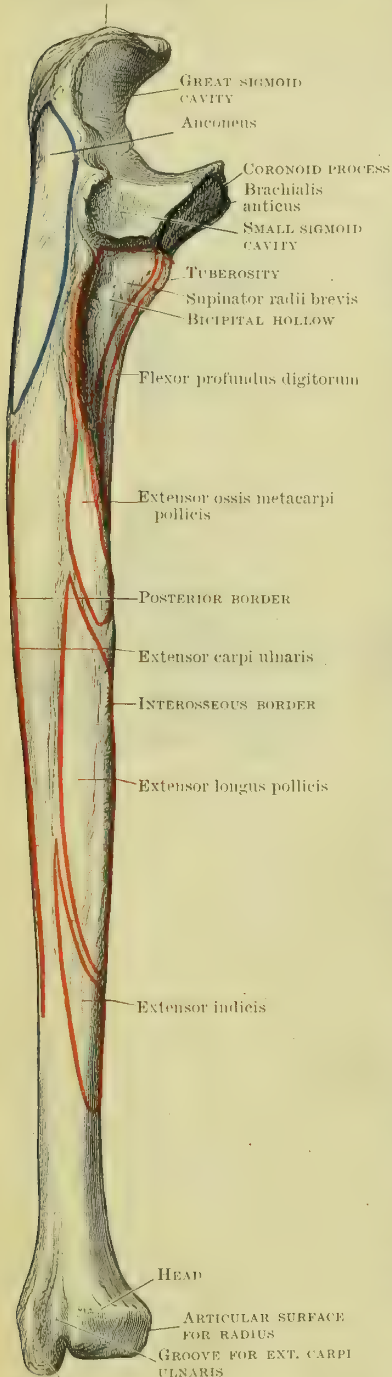


Fig. 134.—The Right Ulna as viewed from the Outer Side.

The **coronoid process** (processus coronoideus) is a bracket-like process, which juts forwards from the fore and upper part of the shaft, and is fused with the olecranon process superiorly. By its upper surface it enters into the formation of the great sigmoid cavity, whilst its anterior aspect, which is separated from its upper side by a sharp irregular margin, slopes downwards and backwards to become confluent with the anterior surface of the shaft. Of triangular shape, this area, which is rough and tubercular, terminates inferiorly in an oval elevated tubercle (tuberositas ulnæ), into which the tendon of the brachialis anticus muscle is inserted. Of the lateral margins of the coronoid process, the inner is usually the better defined. Above, where it joins the superior border, there is generally a salient tubercle, to which one of the heads of origin of the flexor sublimis digitorum muscle is attached, whilst below this point the inner border furnishes origins for the pronator radii teres, and occasionally for the flexor longus pollicis muscles, from above downwards. The smooth inner surface of the coronoid process merges with the olecranon behind, and with the internal surface of the shaft below.

The **great sigmoid cavity** (incisura semilunaris), for articulation with the trochlea of the humerus, is a semicircular notch, the upper part of which is formed by the anterior surface of the olecranon, whilst below it is completed by the upper surface of the coronoid process. Constricted towards its deepest part by the notching of its lateral borders, the articular surface is occasionally crossed by a narrow impression which serves to define the olecranon process above from the coronoid below. The articular area is divided into an inner portion, slightly concave transversely, and an outer part, transversely convex to a slight degree, by a longitudinal smooth ridge which extends from the most prominent part of the border of the olecranon above to the most outstanding point of the coronoid process below. The margins of the great sigmoid cavity are sharp and well defined, and serve, with the exception of the area occupied by the small sigmoid cavity, for the attachment of the capsule of the elbow joint.

The **small sigmoid cavity**, placed on the outer side of the coronoid process, is an oblong articular surface for the reception of the head of the radius. It encroaches

on the lower and outer part of the great sigmoid notch, so as to narrow it considerably. Separated from it by a rectangular curved edge, it displays a surface which is plane from above downwards, and concave from before backwards. Its anterior extremity is narrower and more pointed than its posterior, and becomes confluent with the anterior edge of the coronoid process, at which point the orbicular ligament, which retains the head of the radius in position, is attached in front. Its posterior border, wider and more outstanding, lies in line, and is continuous with the interosseous margin of the shaft. Behind this border, the orbicular ligament is attached posteriorly.

The **shaft** of the ulna (corpus ulnæ), which is nearly straight, or but slightly curved, is stout and thick above, gradually tapering towards its lower extremity. It may be divided into two surfaces, a flexor and an extensor, by two well-defined borders, an **external** or **interosseous** (crista interossea), and a **posterior** (margo dorsalis), which latter is subcutaneous throughout its whole length.

The outer, or **interosseous border** (crista interossea), is crisp and sharp in the upper three-fourths of the shaft, but becomes faint and ill-defined in the lower fourth. To this, with the exception only of the part which forms the posterior boundary of the bicipital hollow, is attached the interosseous membrane which connects the two bones of the forearm. The **posterior border** (margo dorsalis), of sinuous outline, curving outwards above, and slightly inwards below, is continuous superiorly with the triangular subcutaneous area on the back of the olecranon, being formed by the confluence of the borders which bound that surface; well marked above, it becomes faint and more rounded below, but may be traced downwards to the posterior surface of the base of the styloid process. To this border is attached an aponeurosis common to the flexor carpi ulnaris, extensor carpi ulnaris, and flexor profundus digitorum muscles. A noteworthy feature in connexion with this part of the shaft is the fact that it is subcutaneous, and can easily be felt beneath the skin throughout its whole length.

The **flexor surface** corresponds to the front and inner side of the shaft. It is frequently described as consisting of two surfaces, an anterior and an internal, which are separated by a rounder anterior border (margo volaris), which extends from the tubercle above towards the styloid process below. The prominence of this ridge varies in different bones, being well marked in bones of a pronounced type, but corresponding merely to the rounding of the surfaces in poorly developed specimens. The flexor aspect of the bone affords an extensive origin to the flexor profundus digitorum muscle, which clothes its anterior and inner sides in its upper three-fourths, reaching as far back as the posterior border, and extending upwards as high as the inner side of the coronoid process. Immediately below the small sigmoid cavity there is a hollow triangular area, limited behind by the upper part of the interosseous crest, and defined in front by an oblique line which extends downwards and backwards from the outer margin of the coronoid process. In this hollow the bicipital tubercle of the radius rests when the forearm is in the prone position, and to its floor are attached the fibres of origin of the supinator brevis muscle. The lower fourth of the shaft is crossed by the fibres of the pronator quadratus muscle, which derives its origin from a more or less well defined crest, which winds spirally downwards and backwards towards the front of the root of the styloid process, and is continuous above with the so-called anterior border.

The **extensor aspect** of the shaft lies posteriorly between the posterior border and the interosseous crest. At its upper part it is placed behind the great and small sigmoid cavities, extending on to the outer side of the olecranon. Here an area corresponding to the upper third of the length of the bone is marked off inferiorly by an oblique ridge which leaves the interosseous crest about an inch or more below the hinder edge of the small sigmoid cavity. Into this somewhat triangular surface the fibres of the anconeus are inserted. Below this the posterior surface is subdivided by a faint longitudinal ridge, the bone between which and the interosseous crest furnishes origins for the extensor ossis metacarpi pollicis, extensor longus pollicis, and extensor indicis muscles, in order from above downwards. The surface of bone between the posterior border and the afore-mentioned longitudinal line is smooth and overlain by the extensor carpi ulnaris muscle.

The **inferior extremity** of the ulna presents a rounded head (capitulum ulnæ), from which, on its inner and posterior aspect, there projects downwards a cylindrical pointed process called the **styloid process** (processus styloideus). To the extremity of this latter is attached the external lateral ligament, whilst in front it has connected with it the antero-internal portion of the capsule of the wrist joint. The antero-external half of the circumference of the head is furnished with a smooth narrow convex articular surface, which fits into the sigmoid cavity of the radius. Its inferior surface, flat and semilunar in shape, and separated from the root of the styloid process by a well-marked groove, rests on the upper surface of the triangular fibro-cartilage of the wrist, the apex of which is attached to the groove just mentioned. The margins of the head in front and behind the radial articular surface have attached to them the anterior and posterior inferior radio-ulnar ligaments. The hinder and outer surface of the styloid process is channelled by a groove which separates it from the posterior surface of the head, and extends some little way up the posterior aspect of the lower end of the shaft. In this is lodged the tendon of the extensor carpi ulnaris muscle. The proportionate length of the ulna to the body height is as 1 is to 6·26–6·66.

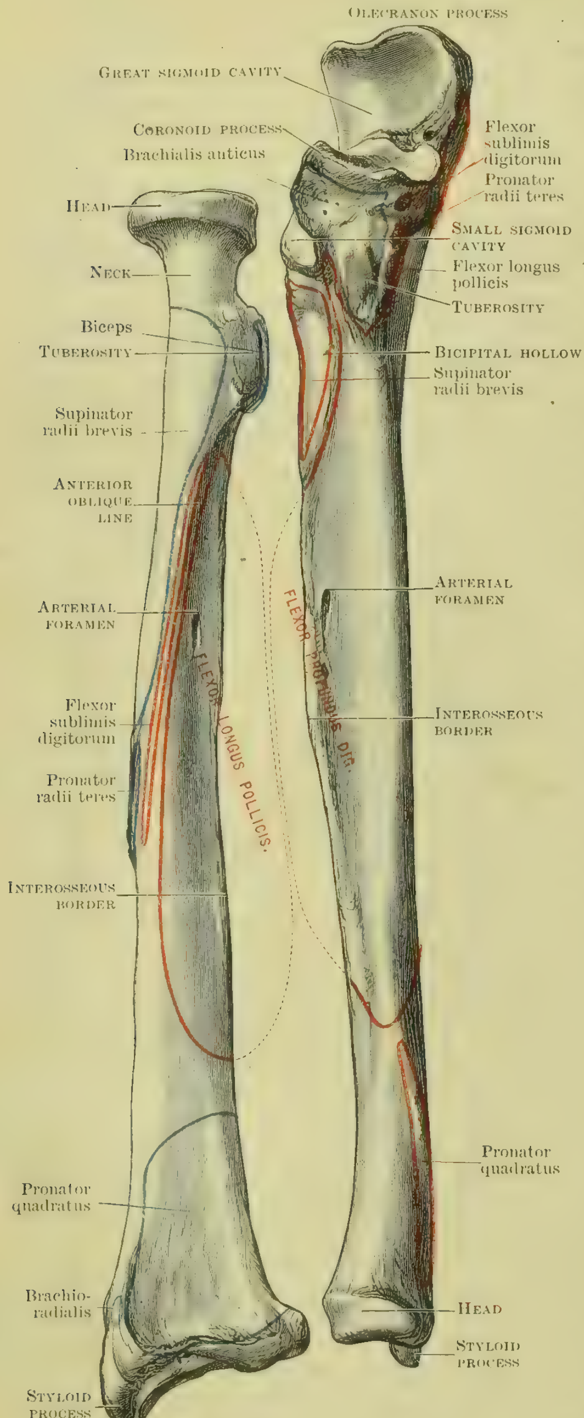


Fig. 135.—The Radius and Ulna as seen from the Front.

Nutrient Foramina.—A foramen, having an upward direction for the nutrient artery of the shaft, opens on the anterior surface of the bone from two to three inches below the tuberosity. Vascular canals of large size are seen above and behind the small sigmoid cavity, just posterior to the notched external border of the great sigmoid cavity. At the lower end of the bone similar openings are seen in the groove between the styloid process and the inferior articular surface of the head.

Connexions.—The ulna articulates above with the trochlea of the humerus. On the outer side it is in contact with the radius above and below, the superior radio-ulnar articulation being formed by the head of the radius and the small sigmoid cavity of the ulna, the inferior radio-ulnar joint comprising the head of the ulna, which fits into the sigmoid cavity of the radius. Between these two joints the shafts of the bones are united by the interosseous membrane. The

inferior surface of the head of the ulna does not articulate with the carpus, but rests on the upper surface of the interposed triangular fibro-cartilage. The ulna is superficial throughout its entire extent. Superiorly the olecranon process can be readily recognised, particularly when the elbow is bent, as in this position the olecranon is withdrawn from the olecranon fossa of the humerus in which it rests when the joint is extended. Below this the subcutaneous triangular area on the back of the olecranon can be easily determined, and from it the posterior border of the bone can readily be traced along the line of the "ulnar furrow" to the styloid process below. With the hand supine this latter process can be felt to the inner side and slightly behind the wrist. When the hand is pronated, the lower end of the radius rolls round the lower extremity of the ulna, and the posterior surface of the head of the latter bone now forms a well-marked projection on the back of the wrist in line with the cleft between the little and ring fingers.

Architecture.—The weakest parts of the bone are the constricted portion of the great sigmoid cavity, and the shaft in its lower third, the bone being most liable to fracture at these points. On section the medullary cavity is seen to extend upwards as high as the base of the coronoid process; inferiorly it reaches as low as the upper end of the lower fifth of the bone. The walls of the shaft, which are formed of dense bone, are much thicker posteriorly than anteriorly. Above they are continuous with the front of the coronoid process and the back of the olecranon, where they are composed of layers of looser texture, which, however, gradually become thinner as the points of these processes are reached. Inferiorly they gradually taper until the head and styloid process are reached, round which they form a thin shell, considerably thickened, however, in the region of the groove for the extensor carpi ulnaris muscle. The bulk of the upper extremity is formed of loose cellular bone, arranged in a series of arcades, stretching from the anterior to the posterior wall over the upper end of the medullary canal. Above the constricted part of the great sigmoid cavity the bone displays a different structure; here it is formed of spongy bone, of closer texture, arranged generally in lines radial to the articular surface. At the point of constriction of the great sigmoid cavity, the layer immediately subjacent is much denser and more compact.

The lower fifth of the bone is formed of loose spongy bone, the fibres of which have a general longitudinal arrangement; towards its extremity the meshes become smaller.

Variations.—Cases of partial or complete absence of the ulna through congenital defect have been recorded. Rosenmüller has described a case in which the olecranon was separated from the upper end of the bone, resembling thus in some respects the patella. In powerfully developed bones there is a tendency to the formation of a sharp projecting crest corresponding to the insertion of the triceps.

Ossification.—The ulna is ossified from one primary and two or more secondary centres. The centre for the shaft appears early in the second month of fœtal life. At birth the shaft and a considerable part of the upper extremity, including the coronoid process, are ossified, as well as part of the lower extremity. The olecranon process and the inferior surface of the head and the styloid process are cartilaginous. About ten years of age a secondary centre appears in the cartilage at the upper end of the bone, and forms an epiphysis which unites with the shaft about sixteen. A scale-like centre appears in the cartilage of the head about the sixth year, from which the under surface of that part of the bone is developed, and by the extension of which the styloid process is also ossified; this epiphysis does not unite with the shaft till the twentieth or twenty-third year. Independent centres for the styloid process and for the extreme edge of the olecranon have also been described. The student may here be warned that the epiphysial line between the shaft and superior or olecranon epiphysis does not correspond to the constricted part of the great sigmoid cavity, but lies considerably above it.

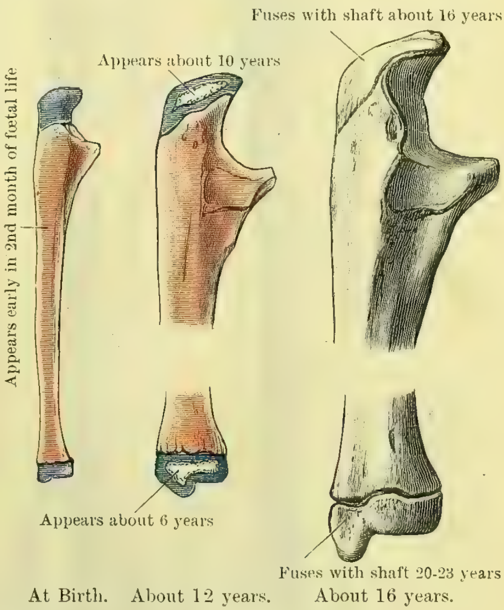


Fig. 136.—The Ossification of the Ulna.

The Radius.

The **radius**, or outer bone of the forearm, is shorter than the ulna, with which it is united on the inner side. Superiorly it articulates with the humerus, and

below supports the carpus. It consists of a head, a neck, a tubercle, a shaft, and an expanded lower extremity. The shaft is narrow above, but increases in all its diameters below.

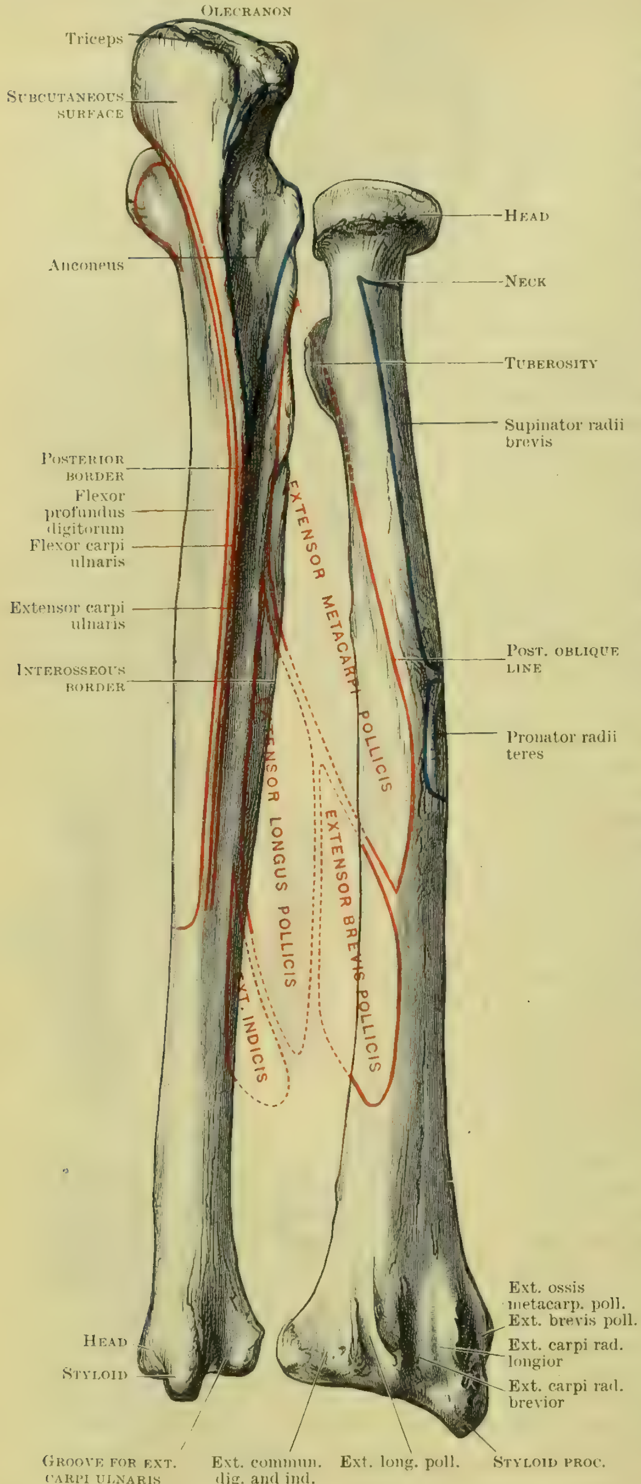


Fig. 137.—The Radius and Ulna as seen from Behind.

Upper Extremity.—The **head** (capitulum) is disc-shaped and provided with a shallow concave surface (fovea cápituli radii) superiorly for articulation with the capitellum of the humerus. The circumference of the head (circumferentia articularis) is smooth and is embraced by the orbicular ligament. On the inner side it is usually much broader, and displays an articular surface, plane from above downwards, which rolls within the small sigmoid cavity of the ulna in the movements of pronation and supination. The character of the outer half of the circumference differs from the inner in being narrower, and rounded from above downwards.

The **neck** (collum radii) is the narrow part of the shaft which supports the head, the overhang of the latter being greatest towards the outer and posterior side. Below the neck, on the inner side, there is an outstanding oval prominence, the **bicipital tuberosity** (tuberositas radii). The posterior half of this is rough for the insertion of the biceps tendon, whilst the anterior half is smooth and covered by a bursa which intervenes between it and the tendon.

The **shaft** (corpus radii), which has an outward curve and is narrow above and broad below, is wedge-shaped on section. The edge of the wedge corresponds to the sharp inner interosseous margin of the bone (crista interossea), whilst its base corresponds to the thick and rounded outer border around which the anterior or flexor surface becomes confluent with the posterior or extensor surface.

The **internal** or **interosseous border**, faint above where it lies in line with the posterior border of the bicipital tubercle, becomes sharp and prominent in the middle third of the bone. Below this it splits into two faint lines, which lead to either side of the sigmoid cavity on the lower end of the bone, thus including between them a narrow triangular area into which the deeper fibres of the pronator quadratus muscle are inserted. To this border, as well as to the posterior of the two divergent lines, the interosseous membrane is attached.

The **external border** (oftentimes described as the external surface) is thick and rounded above, but becomes thinner and more prominent below, where it merges with the base of the **styloid process**. About its middle the anterior and posterior oblique lines become confluent with it, and here, placed between them, is a rough elongated impression which marks the insertion of the pronator radii teres muscle. Above this, and on the outer surface of the neck, the supinator brevis muscle is inserted, whilst this border below is overlain by the tendons of the brachio-radialis and the extensor carpi radialis longior and brevior muscles.

The **anterior** or **flexor surface** (facies volaris) is crossed obliquely by a line which runs from the bicipital tubercle above, downwards and outwards towards the middle of the outer border of the shaft. This, oftentimes called the **anterior oblique line**, serves for the attachment of the radial head of origin of the flexor sublimis digitorum muscle. Above it, the front of the bone has the fibres of the supinator brevis muscle inserted into it, whilst below and internal to it, extending as low as the inferior limit of the middle third of the bone, is an extensive surface for the origin of the flexor longus pollicis muscle. In the lower fourth of the bone, where the shaft is broad and flat in front, there is a surface for the insertion of the pronator quadratus muscle which also extends to the interosseous ridge.

The **extensor** or **posterior surface** (facies dorsalis) is also crossed by an oblique line, less distinct than the anterior. This serves to define the superior limit of the origin of the extensor ossis metacarpi pollicis muscle. Above this, the back of the neck and upper part of the shaft is overlain by the fibres of the supinator brevis, which become attached to this surface of the bone in its outer half. Below the posterior oblique line the posterior surface in the upper part of its inner half gives origin to the extensor ossis metacarpi pollicis, and the extensor brevis pollicis muscles in order from above downwards.

The **lower extremity**, which tends to be turned slightly forward when viewed from below, has a somewhat triangular form. Its inferior **carpal articular surface**, concave from before backwards, and slightly so from side to side, is divided into two facets by a slight antero-posterior ridge, best marked at its extremities where the anterior and posterior margins are notched; the external of these areas, of triangular shape, is for articulation with the scaphoid, whilst the inner, quadrilateral in form, is for the semilunar bone. The anterior border, prominent and turned forward, is rough at its edge, where it serves for the attachment of the anterior part of the capsule of the wrist joint. The posterior border is rough, rounded, and tubercular, and is grooved by many tendons ; of these grooves the best marked is one which passes obliquely across its posterior surface. This is for the tendon of the extensor longus pollicis muscle. The outer lip of this groove is often very prominent, and forms an outstanding tubercle. To the ulnar side of this oblique groove there is a broad shallow furrow in which the tendons of the extensor communis digitorum and extensor indicis muscles are lodged, whilst to its outer side and between it and the styloid process, there is another broad groove, subdivided by a faint ridge into two, for the passage of the tendons of the extensor carpi radialis brevior and the extensor carpi radialis longior in that order from within outwards. The **styloid process** (processus styloideus) lies to the outer side of the inferior extremity ; broad at its base, it becomes narrow and pointed below where by its inner cartilage-covered surface it forms the summit of the inferior triangular articular area. The outer surface of this process is crossed obliquely from above downwards and forwards by a shallow groove, the anterior lip of which is sharp and well marked, and serves to separate it from the anterior surface of the bone, whilst the posterior lip is often emphasised by a small tubercle above. The tendon of the brachio-radialis muscle is inserted into the upper part of either lip, and also spreads out on to the floor of the groove,

whilst the tendons of the extensor ossis metacarpi pollicis and the extensor brevis pollicis muscles lie within the groove. To the tip of the styloid process is attached the external lateral ligament of the wrist. On the inner side of the lower extremity is placed the **sigmoid cavity** (incisura ulnaris) for the reception of the head of the ulna. Concave from before backwards, and plane from above downwards, it forms by its inferior margin a rectangular edge which separates it from the inferior carpal surface. To this edge the base of the triangular fibro-cartilage is attached, a structure which serves to separate the inferior articular surface of the head of the ulna from the carpus. The anterior and posterior edges of the sigmoid cavity, more or less prominent, serve for the attachment of ligaments.

The proportionate length of the radius to the body height is as 1 is to 6·70–7·11.

Nutrient Foramina.—The openings of several small nutrient canals may be seen in the region of the neck. That for the shaft, which has an upward direction, is usually placed on the front of the bone, internal to the anterior oblique line, and from an inch and a half to two inches below the bicipital tubercle. The back of the lower extremity of the bone is pierced by many small foramina.

Connexions. — The radius articulates with the capitellum of the humerus in the flexed position of the elbow, with the ulna to its inner side by the superior and inferior radio-ulnar joints, and with the scaphoid and semilunar bones of the carpus below. Above, the head of the bone can be felt in the intermuscular depression on the outer side of the back of the elbow; here the bone is only covered by the skin, superficial fascia, and the thin common tendinous origin of the extensor muscles, as well as the ligaments which support it. Its position can best be ascertained by pronating and supinating the bones of the forearm, when the head will be felt rotating beneath the finger. The lower end of the bone is overlain in front and behind by the flexor and extensor tendons, but its general form can be readily made out. The styloid process lying to the outer side of the wrist in line with the extended thumb, can easily be recognised: note that it reaches a lower level than the corresponding process of the ulna. The outer border of the lower third of the shaft can be distinctly felt, as here the bone is only overlain by tendons.

Architecture.—The neck is the narrowest part of the bone; here fracture may occur, though not commonly. The point at which the bone is usually broken is about one inch above the lower extremity. This is accounted for by the fact that the radius supports the hand at the radio-carpal articulation, and the shocks to which the latter is subjected, as in endeavouring to save oneself from falling, are naturally transmitted to the radius. On section, the medullary canal is seen to extend as high as the neck; below, it reaches to the level of the inferior fifth of the bone. Its walls are thick as compared with the diameters of the bone, particularly along the interosseous border, thus imparting rigidity to the curve of the shaft; these walls thin out above and below. Superiorly, the surface of the bicipital tubercle is formed of a thin shell of bone, which, however, thickens again where it passes on to the neck. The upper extremity is formed of spongy bone arranged in the form of arcades, reaching below the level of the bicipital tubercle internally, but not extending below the level of the neck externally. Beneath the capitellar articular surface there is a dense layer, thickest in the centre, and thinning towards the circumference; this is overlain by a very thin layer of less compact bone.

The inferior fifth of the shaft and lower extremity are formed of loose spongy bone arranged more or less longitudinally. Immediately subjacent to the carpal articular surface the tissue is more compact, and displays a striation parallel to the articular plane. The nutrient canal of the shaft pierces the anterior wall of the upper part of the medullary cavity obliquely from below upwards for the space of half an inch.

Variations.—Cases of congenital absence of the radius are recorded; in these the thumb is not infrequently wanting as well.

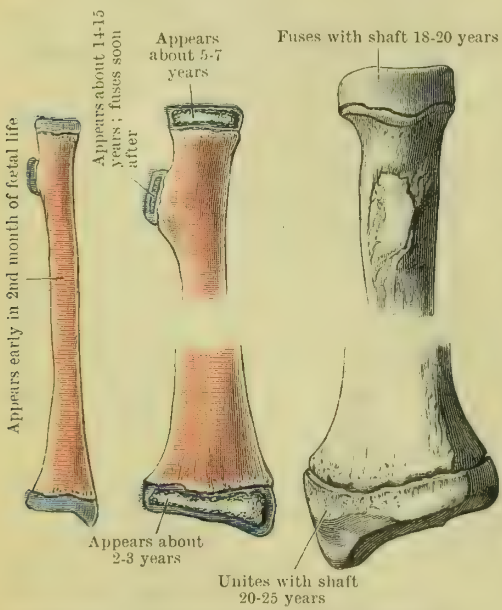


Fig. 138.—The Ossification of the Radius.

Ossification.—The centre for the shaft makes its appearance early in the second month of intrauterine life. At birth the shaft is well formed; its upper and lower extremities are capped with cartilage, and the bicipital tubercle is beginning to appear.

A secondary centre appears in the cartilage of the lower extremity about the second or third year; this does not unite with the shaft until the twentieth or twenty-fifth year, somewhat earlier in the female. From this the carpal and ulnar articular surfaces are formed. The centre for the head appears from the fifth to the seventh year, and fuses with the neck about the age of eighteen or twenty. It forms the capitellar articular surface and combines with the neck to form the area for articulation with the small sigmoid cavity of the ulna. A scale-like epiphysis capping the summit of the bicipital tubercle has been described; this appears about fourteen or fifteen, and rapidly fuses with that process.

THE BONES OF THE HAND.

The bones of the hand, twenty-seven in number, may be conveniently divided into three groups:—

(1) The bones of the wrist or carpus—*eight* in number.

(2) The bones of the palm or metacarpus—*five* in number.

(3) The bones of the fingers and thumb or phalanges—*fourteen* in number.

The Carpus.

The **carpal bones** (ossa carpi) are arranged in two rows: the first or proximal row comprises from without inwards the **scaphoid** (os naviculare), **semilunar** (os lunatum), **cuneiform** (os triquetrum), and **pisiform** (os pisiforme); the second or distal row includes the **trapezium** (os multangulum majus), **trapezoid** (os multangulum minus), **os magnum** (os capitatum), and **unciform** (os hamatum). Irregularly six-sided, each of these bones possesses non-articular palmar and dorsal surfaces. In addition, the marginal bones are non-articular along their ulnar and radial aspects according as they form the inner or outer members of the series.

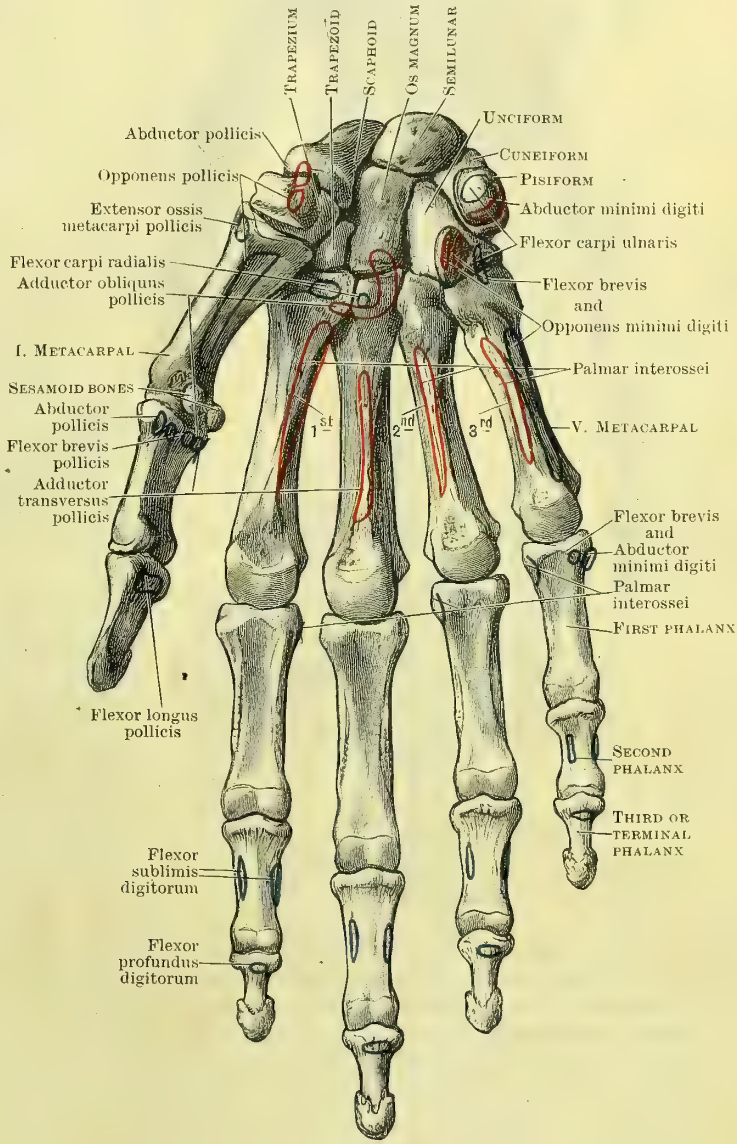


Fig. 139.—The Bones of the Right Wrist and Hand as seen from the Front.

Note.—In the illustrations (Figs. 141 to 148) the bones are represented in the centre of

the figures in the position they occupy in the hand viewed from the front. The views on either side and above and below represent respectively the corresponding surfaces of the bone turned towards the spectator.

Scaphoid Bone (os naviculare).—This is the largest as well as the outermost bone of the first row. Its *palmar surface,* rough for the attachment of ligaments, is irregularly triangular. The inferior external angle forms a projection called the **tuberosity**; this can be felt at the base of the root of the thumb. Its *superior surface* is convex from side to side and before backwards for articulation with the radius. This area extends considerably over the posterior surface of the bone. Its *inferior surface* is convex from before backwards, and extends on to the dorsal aspect of the bone, slightly convex from side to side; it is divisible into two areas, the outer for articulation with the trapezium, the inner for the trapezoid. The *outer surface* is narrow and rounded and forms a non-articular border, which extends from the radial articular surface above to the tuberosity below. The *inner surface* is hollowed out in front for articulation with the head of the os magnum. Above this it displays a small semilunar-shaped facet for the semilunar bone. The *dorsal non-articular surface* lies between the radial articular surface above and the surface for the trapezium and trapezoid below. It is obliquely grooved for the attachment of the posterior ligaments of the wrist. The scaphoid articulates with five bones—the radius, the semilunar, the os magnum, the trapezoid, and the trapezium.

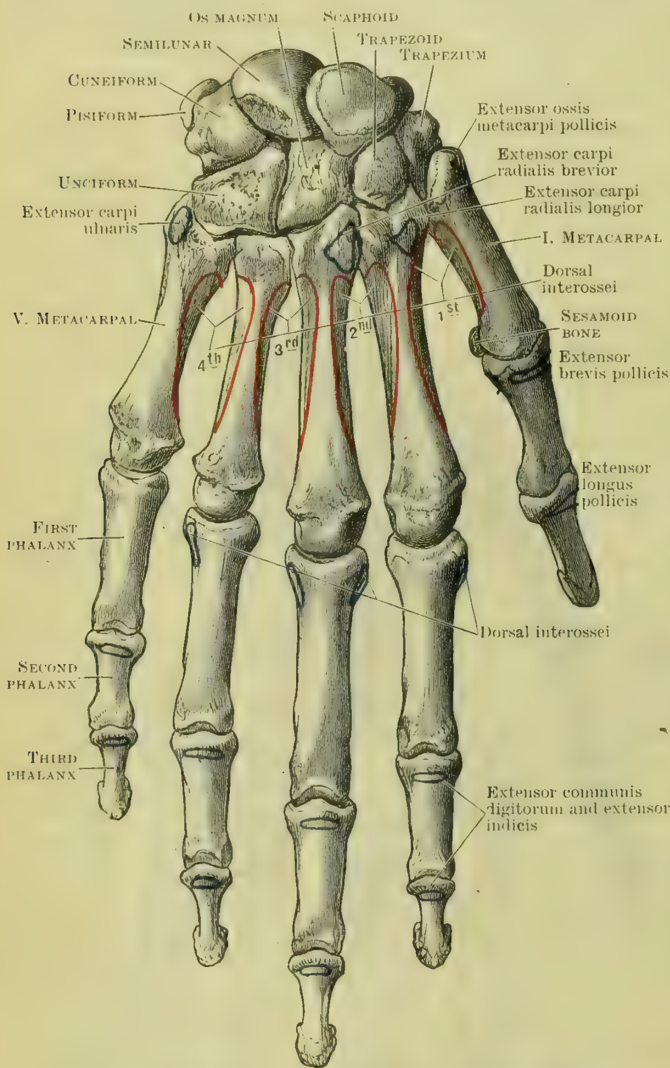


Fig. 140.—The Bones of the Right Wrist and Hand as seen from Behind.

Semilunar Bone (os lunatum).—So called from its deeply excavated form, the semilunar bone lies between the scaphoid on the outer side and the cuneiform on the inner. Its *palmar surface,* of rhombic form and considerable size, is rough for the attachment of ligaments; its *superior surface,* convex from side to side and from before backwards, articulates with the radius and in part with the under surface of the triangular fibro-cartilage of the wrist. Its *inferior aspect,* deeply hollowed from before backwards, is divided into two articular areas, of which the outer is the larger; this is for the head of the os magnum; the inner, narrow from side to side, articulates with the unciform. Its *external surface,* crescentic in shape, serves for

articulation with the scaphoid, and also for the attachment of the interosseous ligaments which connect it with that bone. Its *inner surface*, of quadrilateral form, is cartilage-covered for articulation with the cuneiform, and the edge which separates this from the superior surface has attached to it the interosseous ligament which unites these two bones. The rough *dorsal non-articular surface* is much smaller than the palmar; by this means the front and back of the bone can readily be determined. The semilunar articulates with five bones — the scaphoid, the radius, the cuneiform, the unciform, and the os magnum.

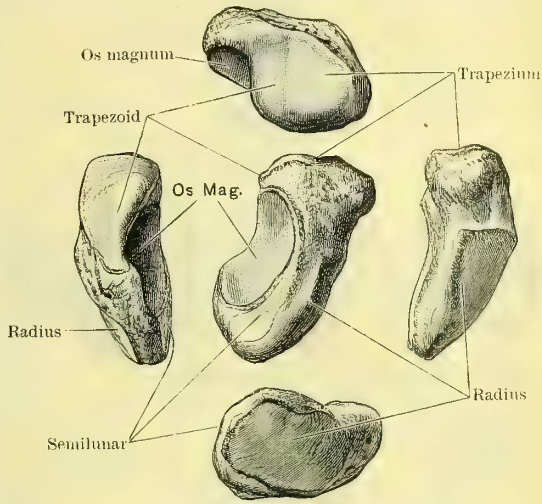


Fig. 141.—The Right Scaphoid Bone.

Cuneiform or **Pyramidal Bone** (os triquetrum).—This bone may be recognised by the small oval or circular facet on its anterior surface for the pisiform. This is placed towards the lower part of the *palmar surface*, which is elsewhere rough for ligaments. The bone is placed obliquely, so that its surfaces cannot be accurately described as inferior, superior, etc.; but for convenience of description, the method already adopted is adhered to. The *superior surface* has a convex rhombic surface for articulation with the under surface of the triangular fibro-cartilage in adduction of the hand, though ordinarily it does not appear to be in contact with that structure. To the ulnar side of this it is rough for ligaments. The *inferior surface* is elongated and concavo-convex from without inwards; here the bone articulates with the unciform. The *external surface*, broader in front than behind, articulates with the semilunar. The *inner surface*, rounded and rough, is confluent above and behind with the superior and dorsal aspects of the bone. The *dorsal surface*, rounded and smooth externally, is ridged and grooved internally for the attachment of ligaments. The cuneiform articulates with three bones, viz. the pisiform, the unciform, and the semilunar.

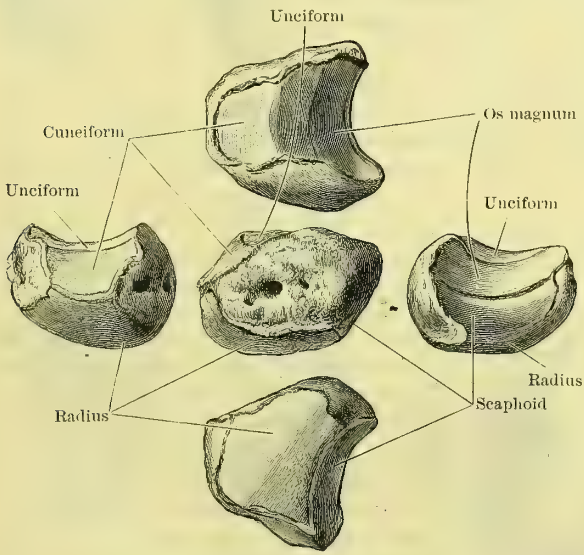


Fig. 142.—The Right Semilunar Bone.

The **pisiform bone** (os pisiforme), about the size and shape of a large pea, rests on the anterior surface of the fore end of the cuneiform, with which it articulates by an oval or circular facet on its dorsal aspect. The rounded mass of the rest of the bone is non-articular, and inclines downwards and outwards so as to overhang the articular facet in front and externally. The mass of the bone is usually separated from the articular surface by a small but distinct groove. Into the summit of the bone the tendon of the flexor carpi ulnaris muscle is inserted, and here also the anterior annular ligament is attached.

Trapezium (os multangulum majus).—The trapezium is the outermost bone of the second row of the carpus. It may be readily recognised by the oval saddle-shaped

facet on its inferior surface for articulation with the metacarpal bone of the thumb. From its *palmar aspect* there rises a prominent **ridge**, within which is a groove along which the tendon of the flexor carpi radialis muscle passes. The ridge furnishes an attachment for the anterior annular ligament, as well as for some of the short muscles of the thumb. The *superior surface* has a half oval facet for the scaphoid, external to which it is rough, and becomes continuous with the non-articular *external aspect*, which serves for the attachment of ligaments. On its *inner surface* there are two facets; the upper is a half oval, concave from above downwards, and very slightly convex from before backwards, and is for articulation with the trapezoid. The lower, small and circular, and not always present, is for articulation with the outer side of the base of the second metacarpal bone. The *dorsal surface*, of irregular outline, is rough for the attachment of ligaments. The trapezium articulates with four bones, the scaphoid, trapezoid, and the first and second metacarpal bones.

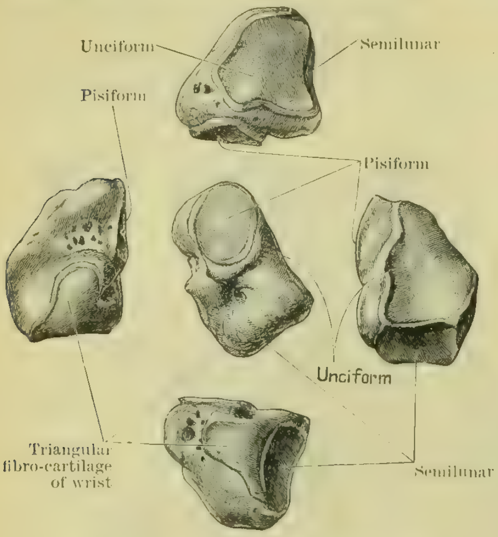


Fig. 143.—The Right Cuneiform Bone.

Trapezoid Bone (os multangulum minus).—With the exception of the pisiform, this is the smallest of the carpal bones. Its rough *palmar surface* is small and pentagonal in outline. By a small oblong surface on its *superior aspect* it articulates with the scaphoid. *Inferiorly*, by a somewhat saddle-shaped surface, it articulates with the base of the second metacarpal. Separated from this by a rough V-shaped impression, is the surface on the *outer side* for articulation with the trapezium; this appears as if obliquely grooved from before backwards and downwards. The *internal facet* for articulation with the os magnum is narrow from above downwards, and deeply curved from before backwards. The *dorsal surface* of the bone, which is rough and non-articular, is much larger than the palmar aspect. The mass of the bone, dorsally, is directed downwards and towards the ulnar side. The trapezoid articulates with four bones—the trapezium, scaphoid, os magnum, and the second metacarpal.

Fig. 144.—The Right Pisiform Bone.

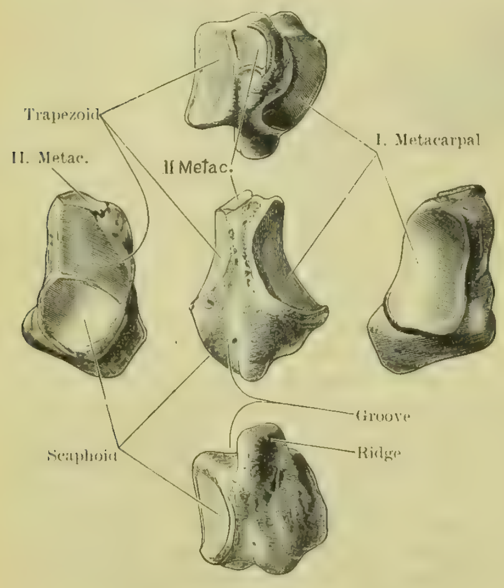


Fig. 145.—The Right Trapezium.

Os Magnum (os capitatum).—This is the largest of the carpal bones. Its *palmar surface* is rough and rounded. The *superior portion* of the bone forms the **head**, and is furnished with convex articular facets which fit into the hollows on the inferior surfaces of the scaphoid and semilunar; that for the latter is internal to and separated by a slight ridge from the scaphoid articular area. The *inferior surface*, narrow towards its palmar border and broad dorsally, is subdivided usually into three

facets by two ridges—that towards the radial side is for the base of the second metacarpal; the middle facet is for the third metacarpal; whilst the innermost facet of the three, not always present, very small and placed near the dorsal side of the bone, is for the fourth metacarpal. The *outer side* of the body has an articular surface for the trapezoid, not infrequently separated from the scaphoid surface on the head by a rough line, to which the interosseous ligament connecting it with the scaphoid is attached. The *inner side* of the body has an elongated articular surface, usually deeply notched in front, or it may be divided anteriorly into a small circular area near the dorsal edge; and a larger posterior part. This latter articulates either singly or doubly with the unciform, the interosseous ligament which unites the two bones being attached either to the notch or to the surface separating the two articular facets. The *dorsal surface* is rough for ligaments; it is somewhat constricted below the head, the articular surface of which sweeps rounds its upper border.

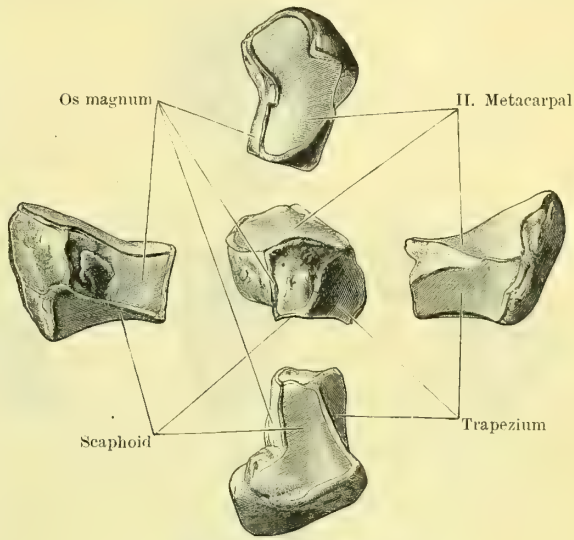


Fig. 146.—The Right Trapezoid.

The os magnum articulates with seven bones—the unciform, the semilunar, the scaphoid, the trapezoid, and the second, third, and fourth metacarpal bones; occasionally the fourth metacarpal does not articulate with the magnum.

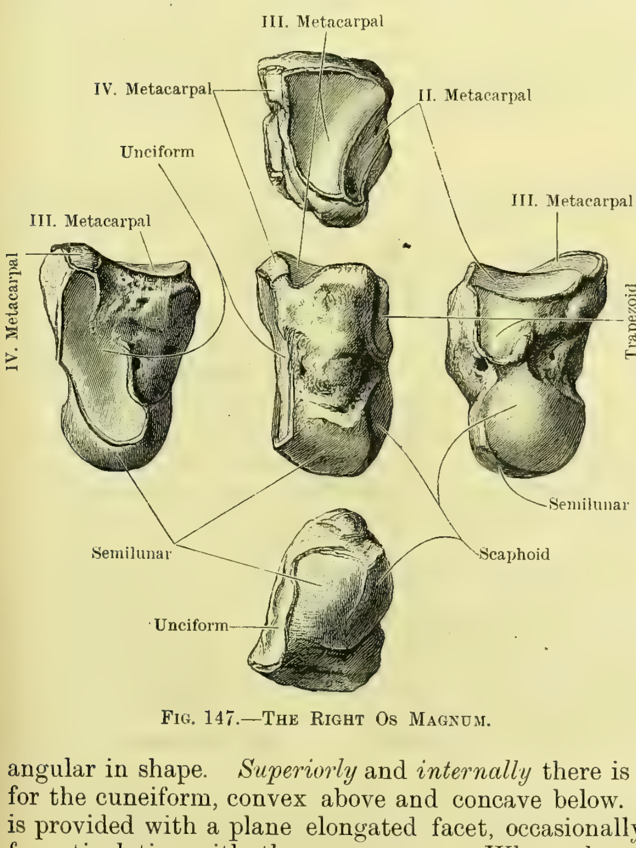


Fig. 147.—The Right Os Magnum.

Unciform Bone (os hamatum).—The unciform can readily be distinguished by the **hook-like process** (hamulus) which projects from the lower and inner aspect of its anterior surface. To this is attached the anterior annular ligament as well as some of the fibres of origin of the short muscles of the little finger. The *ulnar side* of the unciform process is sometimes grooved by the deep branch of the ulnar nerve (Anderson, W., "Proc. Anat. Soc." *Journ. Anat. and Physiol.* vol. xxviii. p. 11). The *palmar surface*, rough for ligaments, is somewhat triangular in shape. *Superiorly* and *internally* there is an elongated articular surface for the cuneiform, convex above and concave below. The *outer aspect* of the bone is provided with a plane elongated facet, occasionally divided into two (see above) for articulation with the os magnum. Where the superior and external surfaces

meet, the angle is blunt, and has a narrow facet which articulates with the semilunar. *Inferiorly* there are two articular facets separated by a ridge; these are slightly concave from before backwards, and are for articulation, the outer with the fourth, and the inner with the fifth metacarpal bone. The *dorsal surface,* more or less triangular in shape, is rough for ligaments.

The unciform articulates with five bones—viz. the os magnum, semilunar, cuneiform, and the fourth and fifth metacarpals.

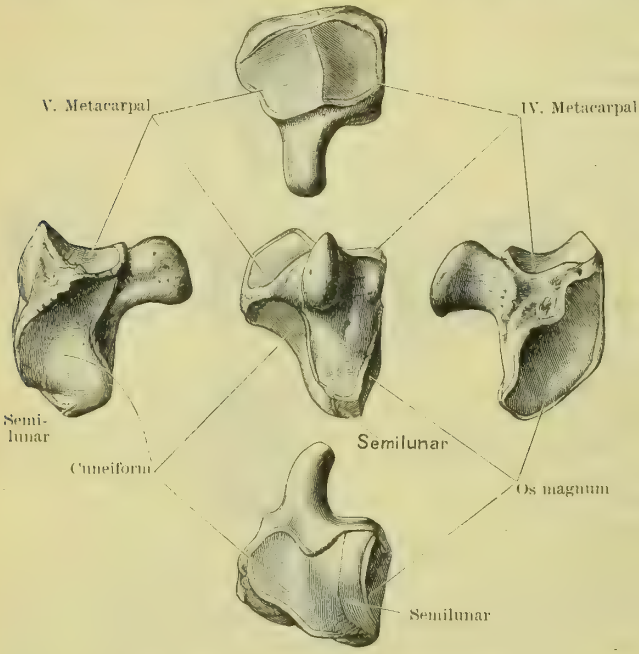


FIG. 148.—THE RIGHT UNCIFORM BONE.

THE CARPUS AS A WHOLE.

When the carpal bones are articulated together they form a bony mass, the dorsal surface of which is convex from side to side. Anteriorly they present a grooved appearance, concave from side to side. This arrangement is further emphasised by the forward projection on the inner side of the pisiform and hook of the unciform, whilst externally the tuberosity of the scaphoid and the ridge of the trapezium help to deepen the furrow by their elevation. To these four points the anterior annular ligament of the wrist is attached, which stretches across from side to side, and thus converts the furrow into a canal through which the flexor tendons pass to reach the fingers.

Architecture.—The bones are formed of fairly compact spongy tissue, surrounded by a thin shell of denser bone. They are very vascular, and their non-articular surfaces are pierced by many foramina.

Variations.—Increase in the number of the carpal elements is occasionally met with, and these have been ascribed to division of the scaphoid, semilunar, cuneiform, os magnum, trapezoid, and unciform. In the last-mentioned case the hook-like process persists as a separate ossicle; but the researches of Thilenius (*Morph. Arbeiten*, Bd. v. Heft 3, S. 462), together with the observations of Pfitzner, prove that all these supernumerary bones are but the persistence of independent cartilaginous elements which are met with in the hand of the human embryo between the second and fourth months, and which either disappear or become fused with adjacent elements. Of these the most interesting is the os centrale, first described by Rosenberg, and subsequently investigated by Henke, Leboucq, and others. This is met with almost invariably as an independent cartilaginous element during the earlier months of fœtal life, and occasionally becomes developed into a distinct ossicle placed on the back of the carpus between the scaphoid and os magnum and the trapezoid. Its significance depends on the fact that it is an important component of the carpus in most mammals, and is met with normally in the orang and most monkeys. Ordinarily in man, as was pointed out by Leboucq, it becomes fused with the scaphoid, where its presence is often indicated by a small tubercle, a condition which maintains in the chimpanzee, the gorilla, and the gibbons.

Further addition to the number of the carpal elements may be due to the separation of the styloid process of the third metacarpal bone and its persistence as a separate ossicle. Reduction in the number of the carpus has been met with, but this is probably due to pathological causes. Morestin (*Bull. Soc. Anat. de Paris*, tome 71, p. 651), who has investigated the subject, finds that ankylosis occurs most frequently between the bases of the second and third metacarpal bones and the carpus, seldom or never between the carpus and the first metacarpal, or between the pisiform and cuneiform.

Ossification.—At birth the carpus is entirely cartilaginous. An exceptional case is figured by Lambertz, in which the centres for the os magnum and unciform were already present. The same authority states that it is not uncommon to meet with these centres

in the second month after birth. According to Debierre (*Jour. de l'Anat. et de la Physiol.* vol. xxii., 1886, p. 285), ossification takes place approximately as follows:—

Os magnum	11 to 12 months.
Unciform	12 to 14 months.
Cuneiform	3 years.
Semilunar	5 to 6 years.
Trapezium	6 years.
Scaphoid	6 years.
Trapezoid	6 to 7 years.
Pisiform	10 to 12 years.

The same observer failed to note the appearance of a separate centre for the apophysis of the unciform, and records the occurrence of two centres for the pisiform.

The Metacarpus.

The **metacarpal bones** form the skeleton of the palm, articulating proximally with the carpus, whilst by their distal extremities or **heads** they support the bones of the fingers. Five in number, one for each digit, they lie side by side and slightly divergent from each other, being separated by intervals, termed interosseous spaces. Distinguished numerically from without inwards, they all display certain common characters; each possesses a **body** or shaft, a **base** or carpal extremity, and a **head** or phalangeal end.

The **shafts**, which are slightly curved towards the palmar aspect, are narrowest towards their middle. Their dorsal surface is marked by two divergent lines which pass forward from the back of the base to tubercles on either side of the head. The surface included between the two lines is smooth and of elongated triangular form. On either side of these lines two broad shallow grooves wind spirally forward on to the palmar surface, where they are separated in front by a sharp ridge which is continuous with a somewhat triangular surface which corresponds to the palmar aspect of the base. The grooved surfaces on either side of the shaft furnish origins for the interossei muscles. Close to the palmar crest is the opening of the nutrient canal, which is directed towards the carpal extremity, except in the case of the first metacarpal bone.

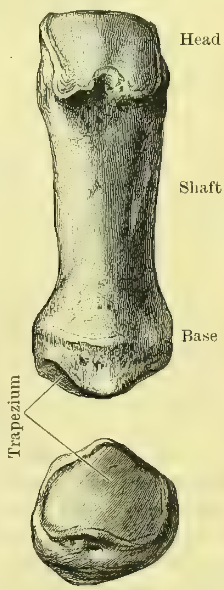


Fig. 149.—First Right Metacarpal Bone.

The **head** (capitulum) is provided with a surface for articulation with the proximal phalanx. This area curves farther over its palmar than its dorsal aspect. Convex from before backwards and from side to side, it is wider anteriorly than posteriorly; notched on its palmar aspect, its edges form two prominent tubercles, which are sometimes grooved for the small sesamoid bones which may occasionally be found on the anterior surface of the joint. On either side of the head of the bone there is a deep pit, behind which is a prominent tubercle; to these are attached the lateral ligaments of the metacarpo-phalangeal joints.

The **bases** (basis), all more or less wedge-shaped in form, articulate with the carpus; they differ in size and shape according to their articulation.

Of the five metacarpal bones, the **first**, viz. that of the thumb, is the shortest and stoutest, the **second** is the longest, whilst the **third, fourth**, and **fifth** display a gradual reduction in length.

The four inner bones articulate by their bases with each other, and are united at their distal extremities by ligaments. They are so arranged as to conform to the hollow of the palm, being concave from side to side anteriorly, and convex posteriorly. The first metacarpal differs from the others in being free at its distal extremity, whilst its proximal end possesses only a carpal articular facet.

The **first metacarpal bone** is the shortest and stoutest of the series. Its shaft

is compressed from before backwards. Its head, of large size, is but slightly convex from side to side, and is grooved in front for the sesamoid bones. The base is provided with a saddle-shaped surface for articulation with the trapezium, and has no lateral facets. Externally there is a slight tubercle to which the abductor longus pollicis muscle is attached. The canal for the nutrient artery is directed towards the head of the bone.

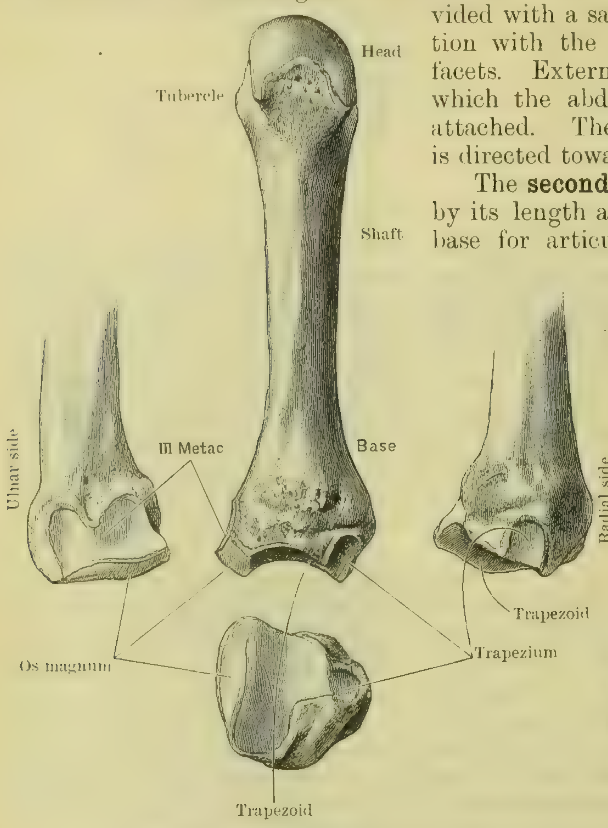


FIG. 150.—SECOND METACARPAL BONE.

The **second metacarpal bone** is recognised by its length and its broad and deeply-notched base for articulation with the trapezoid. It has a small half-oval facet for the trapezium on the radial side of its base, whilst on its ulnar aspect it presents a narrow vertical strip for the os magnum, in front of which there are two half-oval surfaces for the third metacarpal. To the dorsal aspect of the base is attached the tendon of the extensor carpi radialis longior muscle, whilst the flexor carpi radialis is inserted in front.

The **third metacarpal bone** can usually be recognised by the pointed **styloid process** which springs from the back of its base, and is directed radial-wards. Superiorly there is a facet on the base for the os magnum. To the radial side there are two half-oval facets for the second metacarpal. To the ulnar side there are usually two small oval or nearly circular facets for the fourth metacarpal. The extensor carpi radialis brevior muscle is inserted into the back of the base.

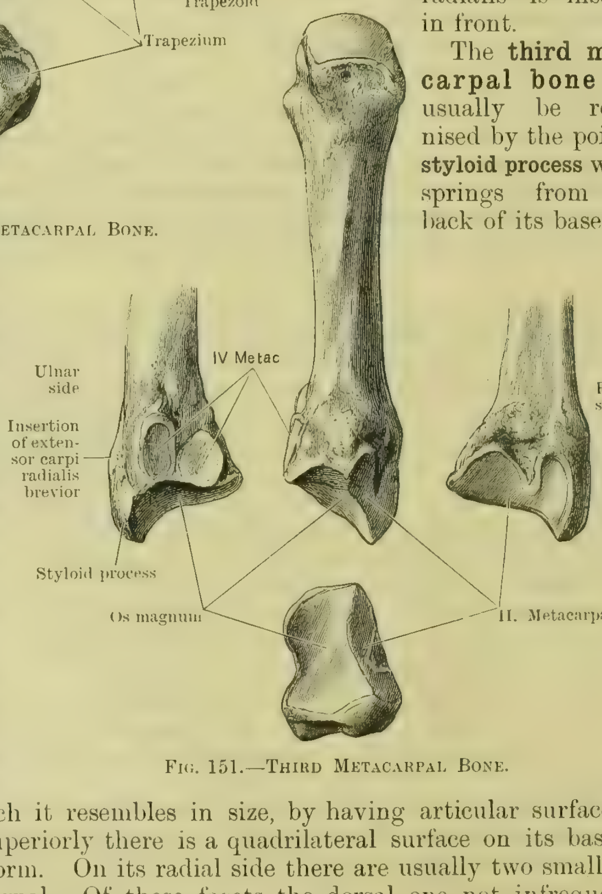


FIG. 151.—THIRD METACARPAL BONE.

The **fourth metacarpal bone** may be recognised by a method of exclusion. It is unlike either the first, second, or third, and differs from the fifth, which it resembles in size, by having articular surfaces on both sides of its base. Superiorly there is a quadrilateral surface on its base for articulation with the unciform. On its radial side there are usually two small oval facets for the third metacarpal. Of these facets the dorsal one not infrequently has a narrow surface for articulation with the os magnum. On the ulnar side there is a narrow articular strip for the base of the fifth metacarpal.

The **fifth metacarpal bone** can be recognised by its size and the fact that it

has only one lateral articular facet on its base, namely, that on its radial side for the fourth metacarpal. The carpal articular surface is saddle-shaped, and there is

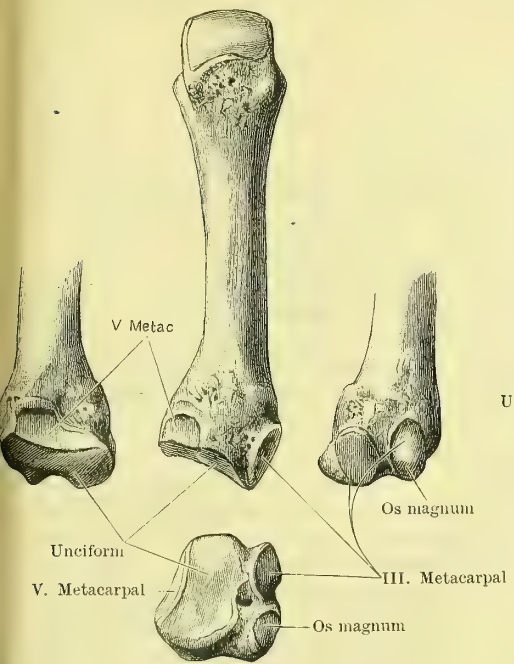


Fig. 152.—Fourth Metacarpal Bone.

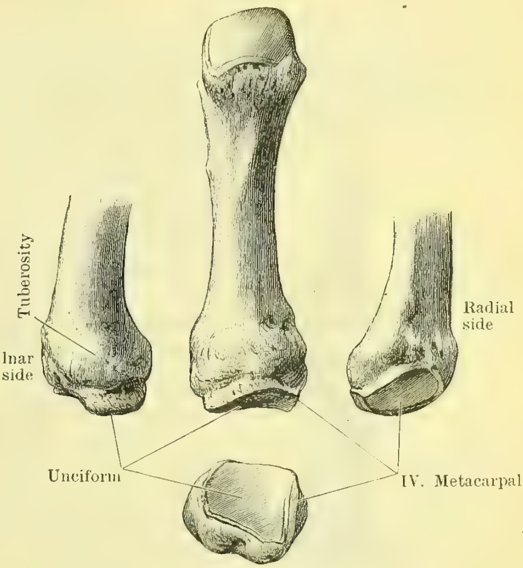


Fig. 153.—Fifth Metacarpal Bone.

a **tubercle** on the ulnar side of the base for the insertion of the extensor carpi ulnaris muscle.

As has been already pointed out, the openings of the arterial canals are usually seen on the palmar surfaces of the metacarpals, those of the four inner bones being directed upwards towards the base or carpal end, differing in this respect from that of the first metacarpal, which is directed downwards towards the head or phalangeal extremity. The opening of the latter canal usually lies to the ulnar side of the palmar aspect of the shaft.

Architecture.—Similar in arrangement to that of long bones generally, though it may be noted that the compact walls of the shaft are thicker in proportion to the length of the bone than in the other long bones of the upper extremity.

Variations.—As previously stated (*ante*, p. 202), the styloid apophysis of the third metacarpal bone appears as a separate ossicle in about 1·8 per cent. of cases examined ("Fourth Annual Report of the Committee of Collect. Invest. Anat. Soc. Gt. Brit. and Ireland," *Journ. Anat. and Physiol.* vol. xxviii. p. 64). In place of being united to the third metacarpal, the styloid apophysis may be fused with either the os magnum or the trapezoid, under which conditions the base of the third metacarpal bone is without this characteristic process.

Ossification.—The metacarpal bones are developed from primary and secondary centres; but there is a remarkable difference between the mode of growth of the first and the remaining four inner metacarpals, for whilst the **shaft** and **head** of the first metacarpal are developed from the primary ossific centre, and its *base* from a secondary epiphysis, in the case of the second, third, fourth, and fifth metacarpals, the **shafts** and **bases** are developed from the primary centres, the *heads* in these instances being derived from the secondary epiphyses. In this respect, therefore, as will be seen hereafter, the metacarpal bone of the thumb resembles the phalanges in the manner of its growth, a circumstance which has given rise to considerable discussion as to whether the thumb is to be regarded as possessing three phalanges and no metacarpal, or one metacarpal and two phalanges. The primary centres for the shafts and bases of the second, third, fourth, and fifth metacarpals appear in that order during the ninth or tenth week of intrauterine life, some little time after the terminal phalanges have begun to ossify, that for the shaft and head of the metacarpal bone of the thumb a little later. At birth the shafts of the bones are well formed. The secondary centres from which the heads of the second, third, fourth, and fifth metacarpals and the base of the first are developed, appear about the third year, and usually completely fuse with the shafts about the age of twenty. There may be an

independent centre for the styloid process of the third metacarpal, and there is usually a scale-like epiphysis on the head of the first metacarpal which makes its appearance about eight or ten, and rapidly unites with the head.

The Phalanges.

The **phalanges** or finger bones (phalanges digitorum manus) are fourteen in number—three for each finger, and two for the thumb.

Named numerically in order from the proximal toward the distal ends of the fingers, the **first phalanx** (phalanx prima), the longest and stoutest of the three, has a semi-cylindrical shaft which is slightly curved forwards. The palmar surface is flat, and bounded on either side by two sharp borders to which the sheath of the flexor tendons is attached. The dorsal surface, convex from side to side, is overlain by the extensor tendons. The proximal end, considerably enlarged, has a simple oval concave surface, which rests on the head of its corresponding metacarpal bone. On either side of this the bone is tubercular, and affords attachment to the lateral ligaments of the metacarpo-phalangeal joint. The distal end is much smaller than the proximal; the convex articular surface is divided into two condyles by a central groove running from before backward. The **second phalanx** (phalanx secunda) resembles the first in general form, but is of smaller size. It differs, however, in the form of its proximal articular surface, which is not a simple oval concavity, but is an oval area divided into two small, nearly circular concavities by a central ridge passing from before backwards; these articulate with the condyloid surfaces of the proximal phalanx. The **third, terminal** or **ungual phalanx** (phalanx tertia), is the smallest of the three; it is easily recognised by the spatula-shaped surface on its distal extremity which supports the nail. The articular surface on its proximal end resembles that on the proximal end of the second phalanx, but is smaller. On the palmar aspect of this end of the bone there is a rough surface for the insertion of the tendon of the flexor profundus digitorum muscle. The phalanges of the thumb resemble in the arrangement of their parts the first and third phalanges of the fingers.

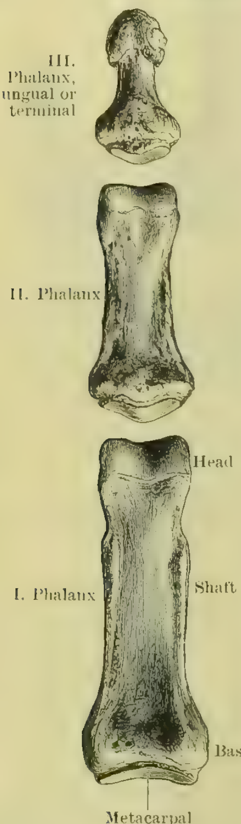


Fig. 154.—The Phalanges of the Fingers (palmar aspect).

The **arterial canals**, usually two in number, placed on either side of the palmar aspect and nearer the distal than the proximal end of the bone, are directed towards the finger-tips.

Architecture.—Each phalanx has a medullary cavity, the walls of the shaft being formed of dense compact bone, especially thick along the dorsal aspect. The extremities are made up of spongy bone within a thin dense shell.

Variations.—Staderini has recorded a case in which there were three phalanges in the thumb (*Inst. Anat. di Firenze G. Chiarurg Monitore Zool. Ital.* Anno 5, N. 6-7, p. 119-123).

Ossification.—The phalanges are ossified from primary and secondary centres. From the former, which appear as early as the ninth week of fœtal life, the shaft and distal extremities are developed; whilst the latter, which begin to appear about the third year, form the proximal epiphyses which unite with the shafts from eighteen to twenty. Dixey (*Proc. Roy. Soc.* xxx. and xxxi.) has pointed out that the primary centre in the ungual phalanges commences to ossify in the distal part of the bone rather than towards the centre of the shaft. This observation has been confirmed by Lambertz, who further demonstrates the fact that ossification commences earlier in the distal phalanges than in any of the other bones of the hand. Of the other phalanges, those of the first row, beginning with that of the third finger, next ossify, subsequent to the appearance of ossific centres in the shafts of the metacarpal bones, whilst the second or intermediate row of the phalanges is the last to ossify about the end of the third month.

Sesamoid Bones.

Two little oval nodules (ossa sesamoidea), which play in grooves on the palmar aspect of the articular surface of the head of the first metacarpal bone, are constantly met with in the tendons and ligaments of that metacarpo-phalangeal articulation. Similar nodules, though of smaller size, are sometimes formed in the corresponding joints of the other fingers, more particularly the index and little finger; as Thilenius has pointed out (*Morph. Arbeiten*, vol. v.), these are but the persistence of cartilaginous elements which have a phylogenetic interest.

THE LOWER LIMB.

THE PELVIC GIRDLE AND THE LOWER EXTREMITY.

The **pelvic girdle** is formed by the articulation of the two haunch bones with the sacrum behind, and their union with each other in front, at the joint called the symphysis pubis.

The Innominate Bone.

The **innominate** or haunch bone (os coxæ) is the largest of the flat bones of the skeleton. It consists of three parts—the **ilium**, the **ischium**, and the **pubis**—primarily distinct, but fused together in the process of growth to form one large irregular bone. The coalescence of these elements takes place in and around the **acetabulum**, a large circular articular hollow which is placed on the outer side of the bone. The expanded wing-like part above this is the ilium; the stout V-shaped portion below and behind it constitutes the ischium; while the >-shaped part to the inner side, and in front and below, forms the pubis. The two latter portions of the bone enclose between them a large aperture of irregular outline, called the **thyroid** or **obturator** foramen (foramen obturatorum), which is placed in front and below, and to the inner side of the acetabulum.

The **ilium**, almost a quadrant in form, consists of an expanded plate of bone, having a curved superior border, the **iliac crest** (crista iliaca). Viewed from the side, this forms a curve corresponding to the circumference of the circle of which the bone is the quadrant; viewed from above, however, it will be seen to display a double bend—convex anteriorly and externally, and concave posteriorly and externally. The iliac crest is stout and thick, and for descriptive purposes it is divided into an outer lip (labium externum), an inner lip (labium internum), and an intermediate surface (linea intermedia) which is broad behind, narrowest about its middle, and wider again in front. About 2½ inches from the anterior extremity of the crest the outer lip is usually markedly prominent and forms a projecting tubercle, which can readily be felt in the living. Attached to these surfaces and lips anteriorly are the muscles of the flank, whilst from them posteriorly the latissimus dorsi, quadratus lumborum, and erector spinæ muscles derive their origins. In front, the crest ends in a pointed process, the **anterior superior iliac spine** (spina iliaca anterior superior). To this the outer extremity of Poupart's ligament is attached, as well as the sartorius muscle, which also arises from the edge of bone immediately below it, whilst from the same process and from the anterior end of the outer lip of the iliac crest externally the tensor fasciæ femoris muscle takes origin.

The **anterior border** of the ilium stretches from the anterior superior iliac spine to the margin of the acetabulum below. Above, it is thin; but below, it forms a thick tubercular process, the **anterior inferior iliac spine** (spina iliaca anterior inferior). From this the rectus femoris muscle arises, whilst strong fibres of the ilio-femoral ligament of the hip-joint are attached to it immediately above the acetabular margin. Posteriorly, the crest terminates in the **posterior superior iliac spine** (spina iliaca posterior superior). Below this, the posterior border of the bone is sharp and irregularly notched, terminating in a prominent angle, the **posterior inferior iliac spine** (spina iliaca posterior inferior), in front of which the edge of the

bone becomes thick and rounded, and forms a wide notch which sweeps forwards and downwards to join the mass of bone behind the acetabulum, where it becomes fused with the ischium; this is called the **ilio-sciatic** or **great sciatic notch** (incisura ischiadica major).

The ilium has two surfaces, an inner and an outer. The *external surface* is divided into two parts, viz. a lower acetabular, and an upper gluteal part. The

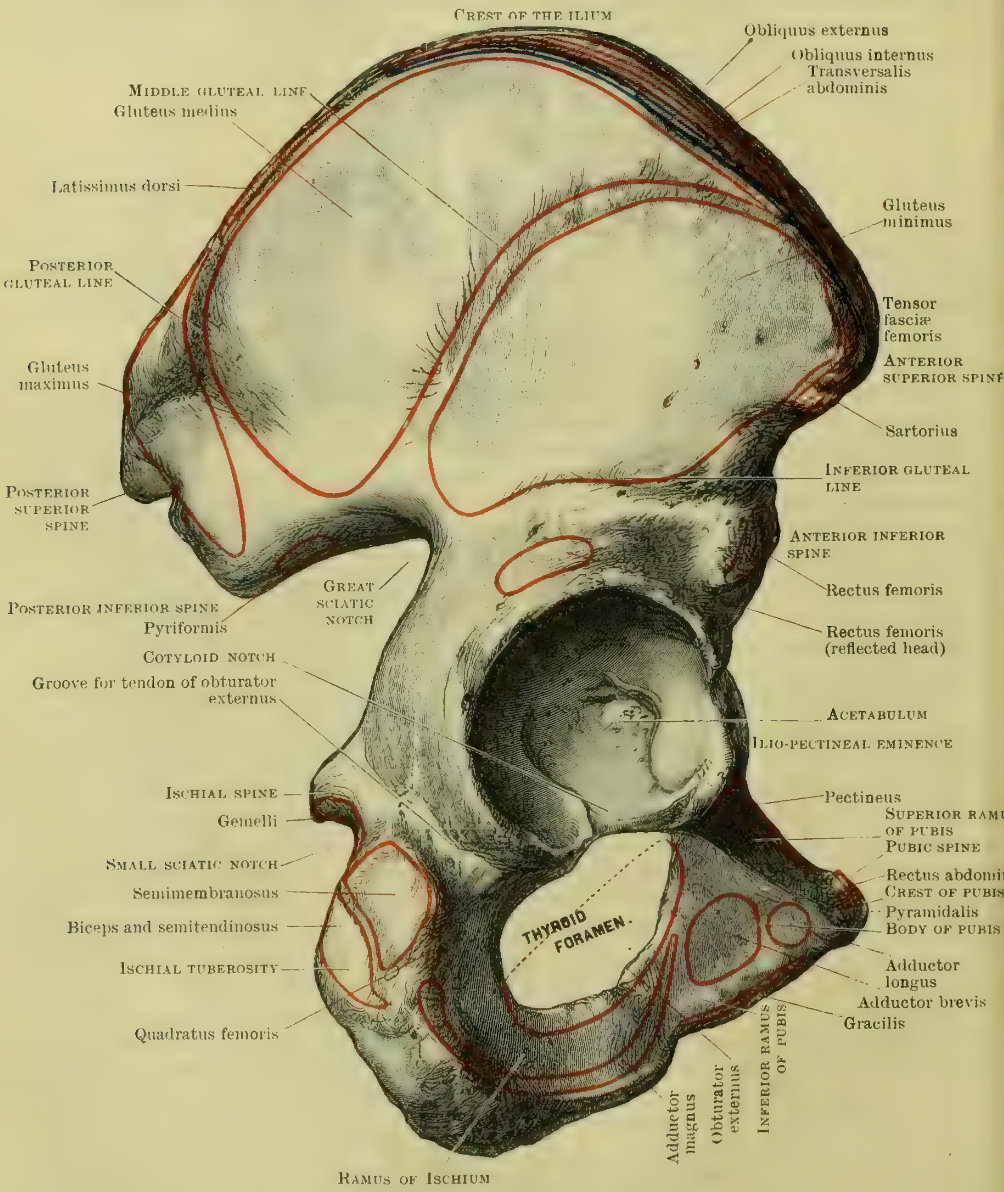


Fig. 155.—The Right Innominate Bone as seen from the Outer Side.

lower forms a little less than the upper two-fifths of the acetabular hollow, and is separated from the larger gluteal surface above by the upper prominent margin of the articular cavity. The **gluteal surface**, broad and expanded, is concavo-convex from behind forward. It is traversed by **three** rough **curved lines**, well seen in strongly developed bones, but often faint and indistinct in feebly marked specimens. Of these the **inferior curved line** (linea glutæa inferior) curves backwards from a point immediately above the anterior inferior spine towards the ilio-sciatic notch posteriorly; the bone between this and the acetabular margin is marked by

a rough, shallow groove, from which the reflected head of the rectus femoris muscle arises. The **middle curved line** (linea glutæa anterior) commences at the crest of the ilium, about one inch and a half behind the anterior superior iliac spine, and sweeps backwards and downwards towards the upper and posterior part of the ilio-

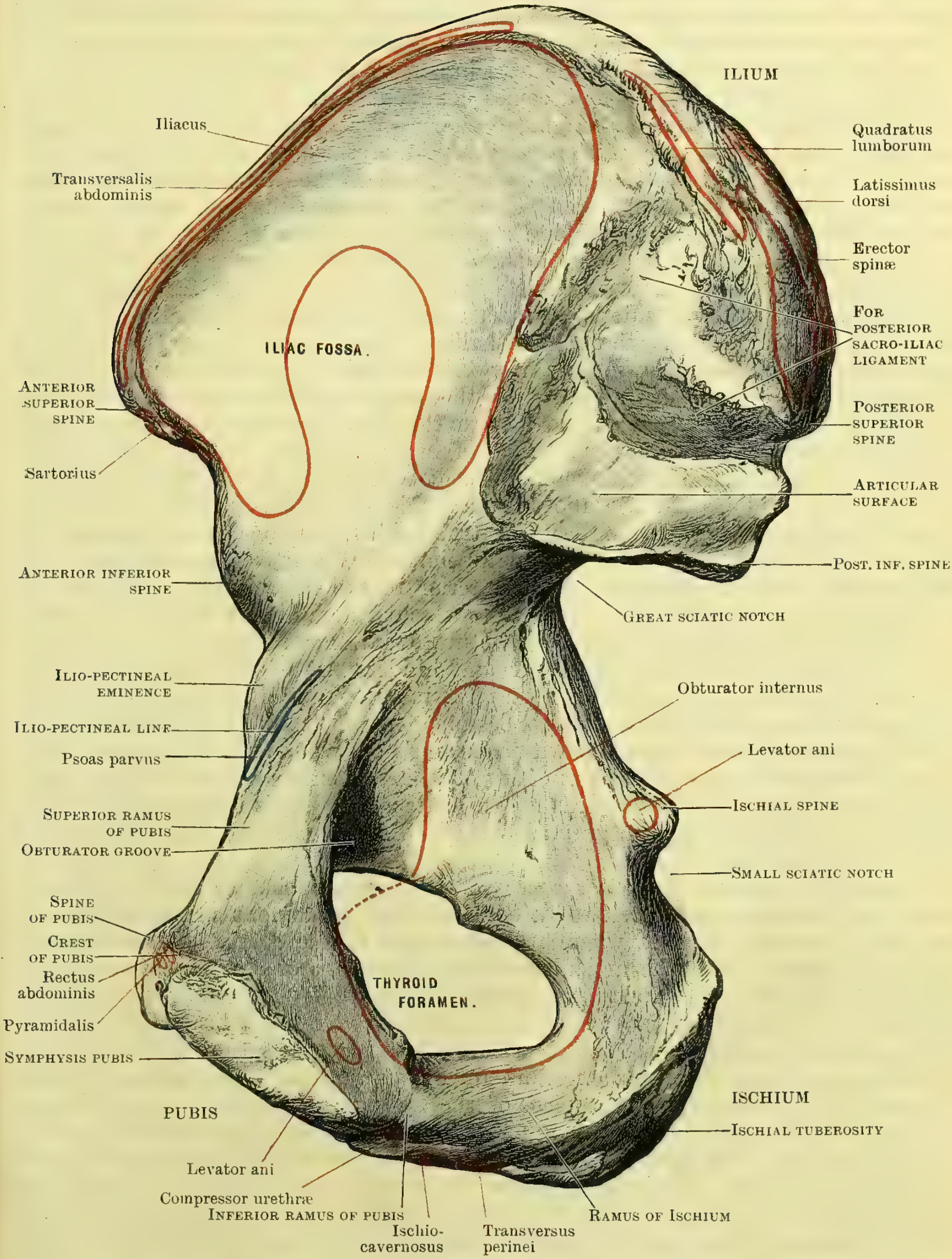


Fig. 156.—The Right Innominate Bone (Inner Aspect).

sciatic notch. The surface between this line and the preceding furnishes an extensive origin for the gluteus minimus muscle. The **posterior** or **superior curved line** (linea glutæa posterior) leaves the iliac crest about two and a half inches in front of the posterior superior iliac spine, and bends downwards and slightly forwards in a direction anterior to the posterior inferior spine. The area between this and the middle curved line is for the origin of the gluteus medius muscle, whilst the rough

surface immediately above and behind it is for some of the fibres of origin of the gluteus maximus muscle.

The *inner surface* of the ilium is divided into two areas which present very characteristic differences. The **posterior** or **sacral part**, which is rough, displays in front a somewhat smooth, auricular surface (facies auricularis) which is cartilage-coated in the recent condition, and articulates with the sacrum. Above and behind this there is an elevated irregular area, the **tuberosity** (tuberositas iliaca), which is here and there deeply pitted for the attachment of the strong posterior sacro-iliac ligaments. Above this the bone becomes confluent with the inner lip of the iliac crest, and here it affords an origin to the erector spinæ and multifidus spinæ muscles. The anterior part of the inner aspect of the bone is smooth and extensive; it is subdivided by an oblique ridge, called the **ilio-pectineal line** (linea arcuata), which passes forwards and downwards from the most prominent point of the auricular surface towards the inner side of the ilio-pectineal eminence which is placed just above and in front of the acetabulum, and marks the fusion of the ilium with the pubis. Above this the bone forms the shallow **iliac fossa** (fossa iliaca), from the floor of which the iliacus muscle arises, whilst leading from the fossa, below and in front, there is a shallow furrow, passing over the superior acetabular margin, between the anterior inferior iliac spine on the outer side and the ilio-pectineal eminence internally, for the lodgment of the tendinous and fleshy part of the ilio-psoas muscle. If held up to the light the floor of the deepest part of the iliac fossa will be seen to be formed of but a thin layer of bone. A nutrient foramen of large size is seen piercing the bone towards the hinder part of the fossa. Below and behind the ilio-pectineal line the inner surface of the ilium forms a small portion of the wall of the true pelvis; the bone here is smooth, and rounded off posteriorly into the ilio-sciatic notch, where it becomes confluent with the inner aspect of the ischium. Just anterior to the ilio-sciatic notch there are usually the openings of one or two large vascular foramina. From this surface arise some of the posterior fibres of the obturator internus muscle.

The **ischium** constitutes the lower and hinder part of the innominate bone. Superiorly its **body** (corpus) forms somewhat more than the inferior two-fifths of the acetabulum together with the bone supporting it behind and within. Below this the **superior ramus** passes downwards and backwards as a stout three-sided piece of bone, from the inferior extremity of which a compressed bar of bone, called the **inferior ramus**, extends forwards at an acute angle. This latter unites in front and above with the descending ramus of the pubis, and encloses the aperture called the obturator foramen.

Superiorly, and on the outer aspect of the ischium, the acetabular surface is separated from the bone below by a sharp and prominent margin, which is, however, deficient in front, where it corresponds to the **cotyloid notch** (incisura acetabuli) leading into the articular hollow; the floor of this notch is entirely formed by the ischium. Below the prominent acetabular margin there is a well-marked groove in which the tendon of the obturator externus lies. Beneath this the antero-external surface of the superior and inferior rami furnish surfaces for the attachments of the obturator externus, quadratus femoris, and adductor magnus muscles. The postero-external surface of the ischium forms the convex surface on the back of the acetabulum. The inner border of this is sharp and well defined, and is confluent above with the border of the ilium, which sweeps round the great or ilio-sciatic notch. From this border, on a level with the lower edge of the acetabulum, there springs a pointed process, the **spine** (spina ischiadica), to which is attached the lesser sacro-sciatic ligament and the superior gemellus muscle. Below this the postero-external surface narrows rapidly, its inner border just below the spine being hollowed out to form the **small sciatic notch** (incisura ischiadica minor). The lower part of this surface and the angle formed by the two rami are capped by an irregularly rough pyriform mass called the **tuberosity** (tuber ischii). This is divided by an oblique ridge into two areas, the upper and outer for the tendon of origin of the semimembranosus muscle, the lower and inner for the conjoined heads of the biceps and semitendinosus muscles. Its prominent inner lip serves for the attachment of the great sacro-sciatic ligament, whilst its outer edge furnishes an

origin for the quadratus femoris muscle; in front and below, the adductor magnus muscle is attached to it.

The *inner surface* of the body and superior ramus of the ischium form in part the wall of the true pelvis. Smooth and slightly concave from before backwards, and nearly plane from above downwards, it is widest opposite the level of the ischial spine. Below this its posterior edge is rounded and forms a groove leading to the small sciatic notch, along and over which the tendon of the obturator internus passes. To part of this surface the fibres of the obturator internus are attached, whilst the inner aspect of the spine supplies points of origin for the coccygeus and levator ani muscles, as well as furnishing an attachment to the "white line" of the pelvic fascia. The inner surface of the inferior ramus of the ischium is smooth, and so rounded that its inferior edge tends to be everted. To this, as well as to its margin, is attached the crus penis, together with the ischio-cavernosus, obturator internus, transversus perinei, and compressor urethræ muscles. In the female, structures in correspondence with these are also found.

The fore-part of the innominate bone is formed by the **pubis**; it is by means of the union of this bone with its fellow of the opposite side that the pelvic girdle is completed in front.

The **pubis** (os pubis) consists of two rami—a **superior, ascending,** or **horizontal** (ramus superior oss. pubis) and an **inferior** or **descending** (ramus inferior oss. pubis). The broad part of the bone formed by the fusion of these two rami is the **body.**

The body is sometimes described as that part of the bone which enters into the formation of the acetabulum, but the English nomenclature has here been followed.

The **body of the pubis** has two surfaces. Of these the *inner* or *posterior* is smooth, and forms the fore-part of the wall of the true pelvis; hereto are attached the levator ani muscle and puboprostatic ligaments. The *anterior* or *external surface* is rougher, and furnishes origins for the gracilis, adductor longus, adductor brevis, and some of the fibres of the obturator externus muscles. The *inner border* is provided with an elongated oval cartilage-covered surface by means of which it is united to its fellow of the opposite side, the joint being called the **symphysis pubis.** The *upper border,* thick and rounded, projects somewhat, so as to overhang the anterior surface. It is called the **crest.** Internally this forms with the inner border or symphysis the **angle,** whilst externally it terminates in a pointed process, the **spine** (tuberculum pubicum). From the crest arise the rectus abdominis and pyramidalis muscles, and to the spine is attached the inner end of Poupart's ligament. Passing upwards and outwards from the outer side of the body towards the acetabulum, of which it forms about the anterior fifth, is the **superior ramus** (ramus superior). This has three surfaces: an antero-superior, an antero-inferior, and an internal or posterior. The *antero-superior surface* is triangular in form. Its apex corresponds to the pubic spine; its anterior inferior border to the **obturator crest** (crista obturatoria), leading from the spine to the upper border of the cotyloid notch; whilst its sharp postero-superior border trends upwards and outwards from the spine, and is continuous with the iliac portion of the ilio-pectineal line just internal to the ilio-pectineal eminence, forming as it passes along the superior ramus the pubic portion of that same line (pecten oss. pubis). On this line, just within the ilio-pectineal eminence, there is often a short sharp crest which marks the insertion of the psoas parvus. The base of the triangle corresponds to the ilio-pectineal eminence above, and the upper margin of the cotyloid notch below. Slightly hollow from side to side, and convex from before backwards, this surface provides an origin for, and is in part overlain by, the pectineus muscle. The *internal* or *posterior surface* of the superior ramus is smooth, concave from side to side, and slightly rounded from above downwards; by its sharp inferior curved border it completes the thyroid foramen, as seen from behind. The *antero-inferior surface* forms the roof of the broad obturator groove (sulcus obturatorius) which passes obliquely downwards and forwards between the lower margin of the antero-superior surface in front and the inferior sharp border of the internal surface behind. The **inferior** or **descending ramus of the pubis** (ramus inferior) passes downwards and outwards from the lower part of the body.

Flattened and compressed, it unites with the inferior ramus of the ischium, and thus encloses the thyroid foramen, whilst in correspondence with its fellow of the opposite side it completes the formation of the pubic arch. *Anteriorly* it furnishes origins for the gracilis, adductor brevis, and adductor magnus muscles, as well as some of the fibres of the obturator externus muscle. Its *inner surface* is smooth, whilst its lower border, rounded or more or less everted, has attached to it the fore-part of the crus penis and the sub-pubic ligament.

The **acetabulum** or **cotyloid cavity** is the nearly circular hollow in which the head of the thigh bone fits. As has been already stated, it is formed by the fusion of the ilium and ischium and pubis in the following proportions: the ilium a little less than two-fifths, the ischium somewhat more than two-fifths, the pubis constituting the remaining one-fifth. It is so placed as to be directed downwards, outwards, and forwards, and is surrounded by a prominent margin, to which the capsule and cotyloid ligament of the hip-joint are attached. Opposite the obturator foramen this margin is interrupted by the **cotyloid notch** (incisura acetabuli); immediately external to the ilio-pectineal eminence the margin is slightly hollowed, whilst occasionally there is a feeble notching of the border above and behind. These irregularities in the outline of the margin correspond to the lines of fusion of the ilium and pubis and the ilium and ischium respectively. The floor of the acetabulum is furnished with a horseshoe-shaped articular surface, which lines the circumference of the hollow, except in front, where it is interrupted by the cotyloid notch. It is broad above; narrower in front and below. Within this articular surface there is a more or less circular rough area (fossa acetabuli) continuous in front and below with the floor of the cotyloid notch. This, somewhat depressed below the surface of the articular area, lodges a quantity of fat, and provides accommodation for the interarticular ligament of the joint. As may be seen by holding the bone up to the light, the floor of this part of the acetabulum is not usually of great thickness. The major part of the non-articular area is formed by the ischium, which also forms the floor of the cotyloid notch.

The **thyroid** or **obturator foramen** (foramen obturatum) lies in front of, below, and internal to the acetabulum. The margins of this opening, which are formed in front and above by the pubis, and behind and below by the ischium, are sharp and thin, except above, where the under surface of the superior ramus of the pubis is channelled by the obturator groove. Below, and on either side of this groove, two tubercles can usually be seen. The one, situated on the edge of the ischium, just in front of the cotyloid notch, is named the **posterior obturator tubercle** (tuberculum obturatorium posterius); the other, placed on the lower border of the inner surface of the superior ramus of the pubis, is called the **anterior obturator tubercle** (tuberculum obturatorium anterius). Between these two tubercles there passes a ligamentous band, which converts the groove into a canal along which the obturator vessels and nerve pass. Elsewhere in the fresh condition the obturator or thyroid membrane stretches across the opening from margin to margin. The form of the foramen varies much, being oval in some specimens, in others more nearly triangular; its relative width in the female is greater than the male.

Nutrient foramina for the ilium are seen on the floor of the iliac fossa, just in front of the sacro-auricular surface; on the pelvic aspect of the bone, close to the great sciatic notch; and on the gluteal surface externally, near the centre of the middle curved line. For the ischium, on its pelvic surface, and also externally on the groove below the acetabulum. For the pubis, on the surface of the body, and deeply also from the acetabular fossa.

Connexions.—The innominate bone articulates with the sacrum behind, with the femur to the outer side and below, and with its fellow of the opposite side internally and in front. Each of its three parts comes into direct relation with the surface. Above, the iliac crest assists in forming the iliac furrow, which serves to separate the region of the flank from that of the buttock. In front, the anterior superior iliac spine forms a definite landmark; whilst behind, the posterior superior iliac spines will be found to correspond with dimples situated on either side of the middle line of the root of the back. The symphysis, the crest, and spine of the pubis can all be distinguished in front, though overlain by a considerable quantity of fat, whilst the position of the tuberosities of the ischia, when uncovered by the great gluteal muscles in the flexed position of the thigh, can readily be ascertained. In the perineal region the outline of the pubic and ischial rami can easily be determined by digital examination.

Architecture.—As a flat bone the os innominatum consists of spongy tissue between two compact external layers. These latter vary much in thickness, being exceptionally stout along the ilio-pectineal line and the floor of the iliac fossa immediately above it. The gluteal aspect of the ilium is also formed by a layer of considerable thickness. The spongy tissue is loose and cellular in the thick part of the ilium and in the body of the ischium; absent where the floor of the iliac fossa is formed by the coalescence of the thin dense confining layers; fine grained and more compact in the tuberosity of the ischium, the iliac crest, and the floor of the acetabulum, in which latter situation it is striated by fibres which are directed radially to the surface of that hollow, these again being crossed at right angles by others which are arranged circumferentially. This spongy tissue forms a more compact layer over the surface of the upper and back portion of the acetabular articular area. The bottom of the floor of the acetabulum varies in thickness; in most cases it is thin and in exceptional instances the bone is here deficient. The same condition has been met with in the iliac fossa, where absorption of the thin bony plate has taken place.

Variations.—Some of the anomalies met with in the haunch bone are due to ossification of the ligaments connected with it; in other cases they depend on errors of development. Failure of union between the pubic and ischial rami has also been recorded. Cases have occurred where the obturator groove has been bridged across by bone, and one case is noted of absence of the cotyloid notch on the acetabular margin. In rare cases the os acetabuli (see Ossification) remains as a separate bone.

Ossification commences in the ilium about the ninth week of intra-uterine life; about the fourth month a centre appears below the acetabulum for the ischium, the pubis being developed from a centre which appears in front of the acetabulum about the fifth or sixth month. At birth the form of the ilium is well defined; the body and part of the tuberosity of the ischium are ossified, as well as the horizontal ramus and part of the body of the pubis. All three parts enter into the formation of the sides of the acetabulum, and by the third year have converged to form the bottom of that hollow, being separated from each other by a triradiate piece of cartilage, in which, about the twelfth year, independent ossific centres make their appearance, which may or may not become fused with the adjacent bones. In the latter case they unite to form an independent ossicle, the os acetabuli, which subsequently fuses with and forms the acetabular part of the pubis. By the age of sixteen the ossification of the acetabulum is usually completed, whilst the rami of the ischium and pubis commonly unite about the tenth year. Secondary centres, six in number, make their appearance about the age of puberty, and are found in the following situations: one for the anterior inferior iliac spine, one for the iliac crest and the anterior and posterior superior iliac spines, a scale-like epiphysis over the tuberosity of the ischium, a separate epiphysis for the spine of the ischium, (?) a point for the spine and another for the angle of the pubis. Fusion between these and the primary centres is usually complete between the twenty-second and twenty-fifth years.

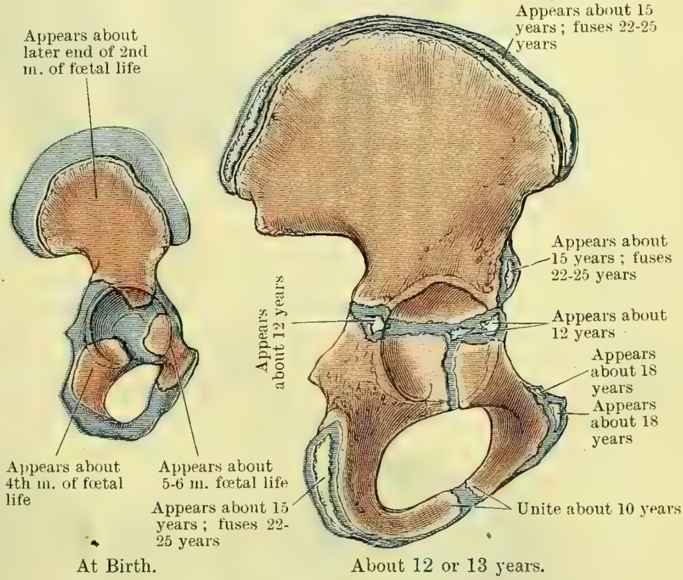


FIG. 157.—OSSIFICATION OF THE INNOMINATE BONE.

THE PELVIS.

The **pelvis** is formed by the union of the innominate bones with each other in front, and with the sacrum behind. In man the dwarfed caudal vertebræ (coccygeal) are curved forwards and so encroach upon the limits of the pelvic cavity inferiorly. The pelvis is divided into two parts by the ilio-pectineal lines, which curve forwards from the upper part of the lateral masses of the sacrum behind, to the roots of the spines of the pubes in front. The part above is called

the **false pelvis** (pelvis major), and serves by the expanded iliac fossæ to support the abdominal contents; the part below, the **true pelvis** (pelvis minor) contains the pelvic viscera, and in the female forms the bony canal through which, at full term, the fœtus is expelled.

The **true pelvis** is bounded in front by the body and rami of the pubis on either side, with the symphysis pubis in the middle line, laterally by the smooth inner surfaces of the ischia and ischial rami, together with a small part of the ilium below the iliac portion of the ilio-pectineal line. Springing from the posterior margin of the ischium are the inturned ischial spines. Behind, the broad curved anterior surface of the sacrum, and below it, the small and irregular coccyx, form its posterior wall. Between the sides of the sacrum behind, and the ischium and ilium in front and above, there is a wide interval, called the **sacro-sciatic notch**, which is, however, bridged across in the recent condition by the great and small sacro-sciatic ligaments, which thus convert it into two foramina, the larger above the spine of the ischium—the great sacro-sciatic foramen, the lower and smaller below the spine, called the small sacro-sciatic foramen.

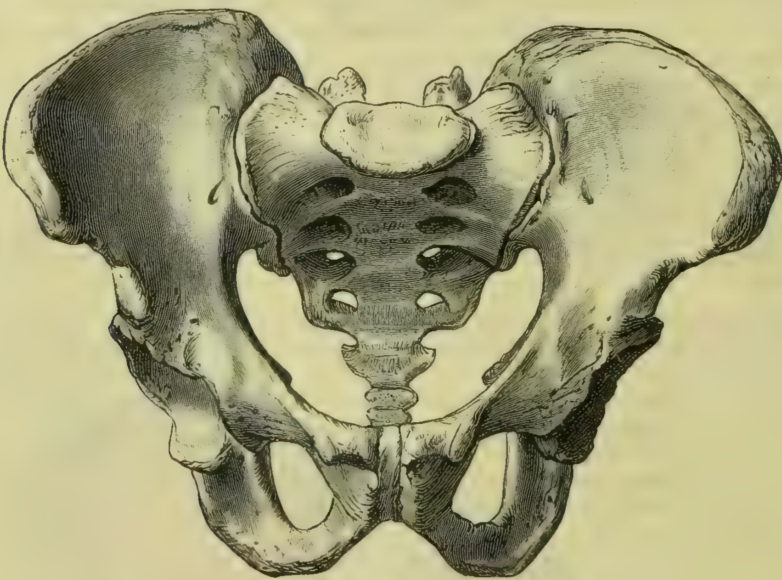


FIG. 158.—MALE PELVIS AS SEEN FROM THE FRONT.

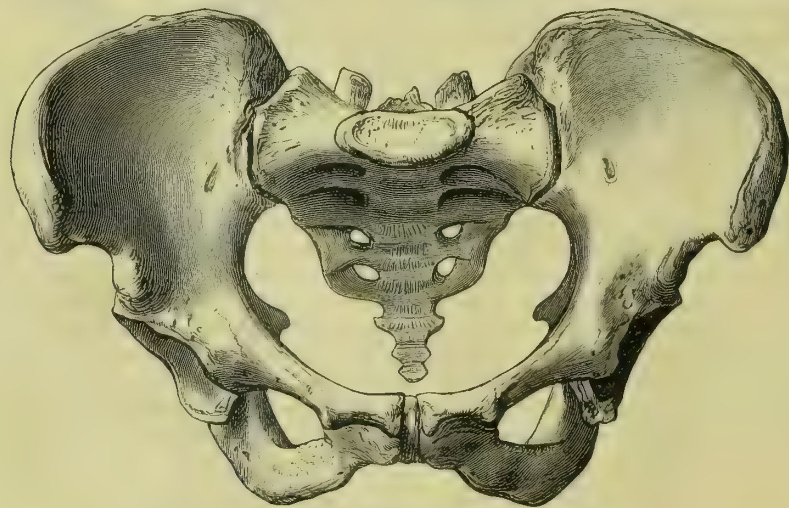


FIG. 159.—FEMALE PELVIS AS SEEN FROM THE FRONT.

The **inlet** (apertura pelvis superior) of the pelvis is bounded in front by the symphysis pubis, with the body of the pubis on either side; laterally by the ilio-pectineal lines; and behind by the sacral prominence. The circumference of this aperture is often called the **brim of the pelvis**; in the male its shape is cordate, in the female more oval. The *antero-posterior* or *conjugate diameter* is measured from the sacro-vertebral angle to the symphysis pubis; the *oblique diameter* from the sacro-iliac joint of one side to the ilio-pectineal eminence of the other; whilst the *transverse diameter* is taken across the point of greatest width.

The **outlet** (apertura pelvis inferior) is bounded anteriorly by the **pubic arch** (arcus pubis), formed in front and above by the bodies of the pubis, with the symphysis between them, and the inferior pubic rami below and on either side. These latter are continuous with the ischial rami which pass backwards and outwards to the ischial tuberosities, which are placed on either side of this aperture. In the middle line and behind, the tip of the coccyx projects forward, and in the recent condition the interval between this and the ischial tuberosities is bridged across by the great sacro-sciatic ligament, the inferior edge of which necessarily assists in determining the shape of the outlet.

As the anterior wall of the cavity, formed by the symphysis pubis, measures from $1\frac{1}{2}$ to 2 inches, whilst the posterior wall, made up of the sacrum and coccyx, is from 5 to 6 inches in length, it follows that the planes of the inlet and outlet are not parallel, but placed at an angle to each other. The term **axis of the pelvis** is given to lines drawn at right angles to the centre of these planes. Thus, with the pelvis in its true position, when the figure is erect, the axis of the inlet corresponds to a line drawn downwards and backwards from the umbilicus towards the tip of the coccyx below, whilst the axis of the outlet is directed downwards and slightly backwards, or downwards and a little forwards, varying according to the length of the coccyx. Between these two planes the axis of the cavity, as it passes through planes of varying degrees of obliquity, describes a curve repeating pretty closely the curve of the sacrum and coccyx.

Position of the Pelvis.—The position of the pelvis in the living when the figure is erect may be approximately represented by placing it so that the anterior superior iliac spines and the symphysis pubis lie in the same vertical plane. Under these conditions the plane of the inlet is oblique, and forms with a horizontal line an angle of from 50° to 60°. The position of the pelvis depends upon the length of the ilio-femoral ligaments of the hip-joint, being more oblique when these are short, as usually happens in women in whom the anterior superior iliac spines tend to lie in a plane slightly in advance of that occupied by the symphysis pubis. In cases where the ilio-femoral ligament is long, a greater amount of extension of the hip-joint is permitted, and this leads to a lessening of the obliquity of the pelvis. This condition, which is more typical of men, results in the anterior superior iliac spines lying in a plane slightly posterior to the plane of the symphysis, whilst the angle formed by the plane of the inlet and the horizontal is thereby reduced. Bearing in mind the oblique position of the pelvis, it will now be seen that the front of the sacrum is directed downwards more than forwards, and that the sacral promontory is raised as much as from $3\frac{1}{2}$ to 4 inches above the upper border of the symphysis pubis, lying higher than the level of a line connecting the two anterior superior iliac spines. From the manner in which the sacrum articulates with the ilia, it will be noticed that the weight of the trunk is transmitted downwards through the thickest and strongest part of the bone (see Architecture) to the upper part of the acetabula, where these rest on the heads of the femora.

Sexual Differences.—The female pelvis is lighter in its construction than that of the male; its surfaces are smoother, and the indications of muscular attachments less marked. Its height is less and the splay of its walls not so pronounced as in the male, so that the female pelvis has been well described as a short segment of a long cone as contrasted with the male pelvis, which is a long segment of a short cone. The cavity of the true pelvis in the female is more roomy, and the ischial spines not so much inturned. The pubic arch is wide and rounded, and will usually admit a right-angled-set square being placed within, so that the summit touches the under surface of the symphysis pubis, whilst the sides lie in contact with the ischial rami. In the male the arch is narrow and angular, forming an angle of from 65° to 70°. The sacro-sciatic notch in the female is wide and shallow. The distance from the posterior edge of the body of the ischium to the

posterior inferior iliac spine is longer, measuring on an average 50 mm. (2 inches) in the female, as contrasted with 40 mm. ($1\frac{5}{8}$ inches) in the male.

The inlet in the female is large and oval or reniform, as compared with the cribbed and heart-shaped aperture in the male. The sacro-vertebral angle is more pronounced in the female, and the obliquity of the inlet greater. The sacrum is shorter and wider. The posterior superior iliac spines lie wider apart; the pubic crests are longer; and the pubic spines are separated by a greater interval than in man. The outlet is larger; the tuberosities of the ischia are far apart; and the coccyx does not project forward so much. The curve of the sacrum is liable to very great individual variation. As a rule the curve is more uniform in the male, whilst in the female it tends to be flatter above and more accentuated below. There is a greater proportionate width between the acetabular hollows in the female than in the male. Of much importance from the standpoint of the obstetrician are the various diameters of the true pelvis. In regard to this it is worthy of note that the plane of "greatest pelvic expansion" extends from the union between the second and third sacral vertebræ behind, to the middle of the symphysis pubis in front, its lateral boundaries on either side corresponding with the mid-point of the inner surface of the acetabulum; whilst the plane of "least pelvic diameter" lies somewhat lower, and is defined by lines passing through the sacro-coccygeal articulation, the ischial spines, and the lower third of the symphysis pubis (Norris). Subjoined is a table showing the principal average measurements in the two sexes:—

	Males.	Females.
Maximum distance between the iliac crests .	$11\frac{1}{8}$ in., or 282 mm.	$10\frac{3}{4}$ in., or 273 mm.
Distance between the anterior superior iliac spines	$9\frac{1}{2}$ in., or 240 mm.	$9\frac{3}{4}$ in., or 250 mm.
Distance between the last lumbar spine and the front of the symphysis pubis	7 in., or 176 mm.	$7\frac{1}{8}$ in., or 180 mm.

TRUE PELVIS.

	MALES.		FEMALES.			
	Inlet.	Outlet.	Inlet.	Cavity.		Outlet.
				Greatest.	Least.	
Antero-posterior (conjugate) diameter	4 in., or 101 mm.	$3\frac{3}{4}$ in., or 95 mm.	$4\frac{3}{8}$ in., or 110 mm.	5 in., or 127 mm.	$4\frac{3}{8}$ in., or 110 mm.	$4\frac{1}{2}$ in., or 115 mm.
Oblique diameter . .	$4\frac{3}{4}$ in. or 120 mm.	$3\frac{1}{2}$ in., or 88 mm.	5 in., or 125 mm.	...	...	$4\frac{1}{2}$ in., or 115 mm.
Transverse diameter .	5 in., or 127 mm.	$3\frac{1}{2}$ in., or 88 mm.	$5\frac{1}{4}$ in., or 135 mm.	$4\frac{7}{8}$ in., or 125 mm.	$4\frac{3}{8}$ in., or 110 mm.	$4\frac{3}{8}$ in., or 110 mm.

Growth of the Pelvis.—From the close association of the pelvic girdle with the lower limb we find that its growth takes place concurrently with the development of that member. At birth the lower limbs measure but a fourth of the entire body length; consequently at that time the pelvis, as compared with the head and trunk, is relatively small. At this period of life the bladder in both sexes is in greater part an abdominal organ, whilst in the female the uterus has not yet sunk into the true pelvic cavity, and the ovaries and Fallopian tubes rest in the iliac fossæ. The sacro-vertebral angle, though readily recognised, is as yet but faintly marked. Coincident with the remarkable growth of the lower limbs and the assumption of the erect position when the child begins to walk, striking changes take place in the form and size of the pelvis. These consist in a greater expansion of the iliac bones necessarily associated with the growth of the muscles which control the movements of the hip, together with a marked increase in the sacro-vertebral angle due to the development of a forward lumbar curve; at the same time, the weight of the trunk being thrown on the sacrum causes the elements of that bone to sink to a lower level between the innominate bones. The cavity of the true pelvis increases in size proportionally, and the viscera afore-mentioned now begin to sink down and have assumed a position within the pelvis by the fifth or sixth year. The extension of the thighs in the upright position necessarily brings about a more pronounced pelvic obliquity, whilst the stoutness and thickness of the ilium over the upper part of the acetabulum is much increased to withstand the pressure to which it is obviously subjected. Coincident with this is the gradual development

of the iliac portion of the ilio-pectineal line, which serves in the adult to separate sharply the false from the true pelvis. This part of the bone is remarkably strong, as has been shown (see Architecture), and serves to transmit the body weight from the sacrum to the thigh bone. The sexual differences of the pelvis, so far as they refer to the general configuration of this part of the skeleton, are as pronounced at the third or fourth month of fœtal life as they are in the adult (Fehling, *Ztschr. f. Geburtsh. u. Gynaek.*, Bd. ix. and x.; A. Thomson, *Journ. Anat. and Physiol.*, vol. xxxiii. p. 359). The rougher appearance of the male type is correlated with the more powerful muscular development.

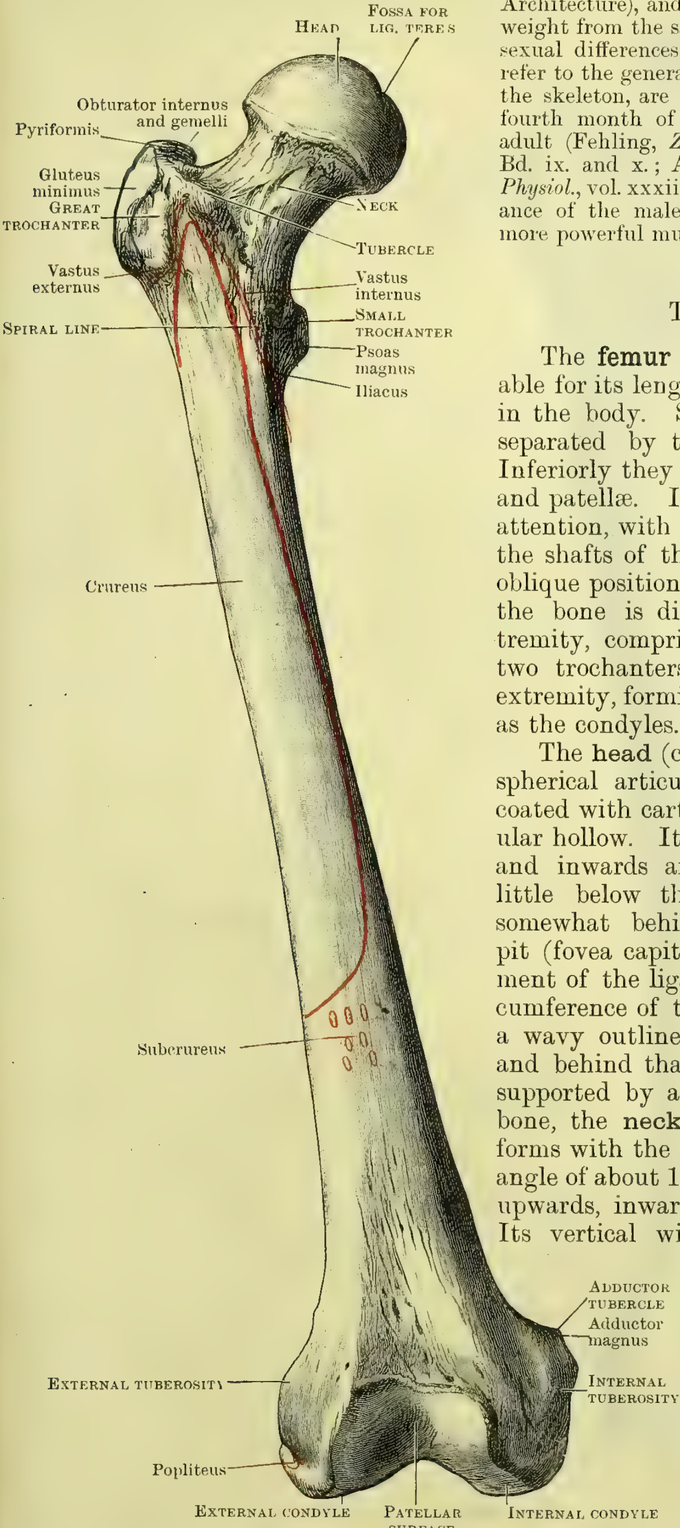


Fig. 160.—Right Femur as seen from the Front.

The Femur.

The **femur** or thigh bone is remarkable for its length, being the longest bone in the body. Superiorly the femora are separated by the width of the pelvis. Inferiorly they articulate with the tibiæ and patellæ. In the military position of attention, with the knees close together, the shafts of the thigh bones occupy an oblique position. For descriptive purposes the bone is divided into an upper extremity, comprising the head, neck, and two trochanters; a shaft; and a lower extremity, forming the expansions known as the condyles.

The **head** (caput femoris) is the hemispherical articular surface which, when coated with cartilage, fits into the acetabular hollow. Its pole is directed upwards and inwards and slightly forwards. A little below the summit, and usually somewhat behind it, is a hollow oval pit (fovea capitis femoris) for the attachment of the ligamentum teres. The circumference of the head forms a lip with a wavy outline, more prominent above and behind than in front. The head is supported by a stout compressed bar of bone, the **neck** (collum femoris), which forms with the upper end of the shaft an angle of about 125 degrees, and is directed upwards, inwards, and a little forwards. Its vertical width exceeds its antero-posterior thickness. Constricted about its middle, it expands internally to support the head, whilst externally, where it joins the shaft, its vertical diameter is much increased. Anteriorly it is clearly defined from the shaft by a rough ridge which commences above on a prominence, sometimes called the **tubercle** of the femur, and passes obliquely down-

wards and inwards. This constitutes the upper part of the **spiral line** (linea intertrochanterica), and serves for the attachment of the ilio-femoral ligament of the hip-joint. Posteriorly, where the neck unites with the shaft, there is a full rounded ridge passing from the trochanter major above to the trochanter minor below; this is the posterior **intertrochanteric line** or **ridge** (crista intertrochanterica). A little above the middle of this ridge there is usually a fulness which serves to indicate the upper limit of attachment of the quadratus femoris muscle, and is called the **tubercle for the quadratus**. Externally the neck is embedded in the inner surface of the trochanter major, by which, at its upper and back part, it is to some extent overhung. Here is situated the **digital fossa** (fossa trochanterica), into which the tendon of the obturator externus is inserted. Passing nearly horizontally across the back of the neck there is a faint groove leading into this depression; in this the tendon of the obturator externus muscle lies. Inferiorly the neck becomes confluent with the trochanter minor behind, and is continuous with the inner surface of the shaft in front. The neck is pierced by many vascular canals, most numerous at the upper and back part. Some are directed upwards towards the head, whilst others pass in the direction of the trochanter major.

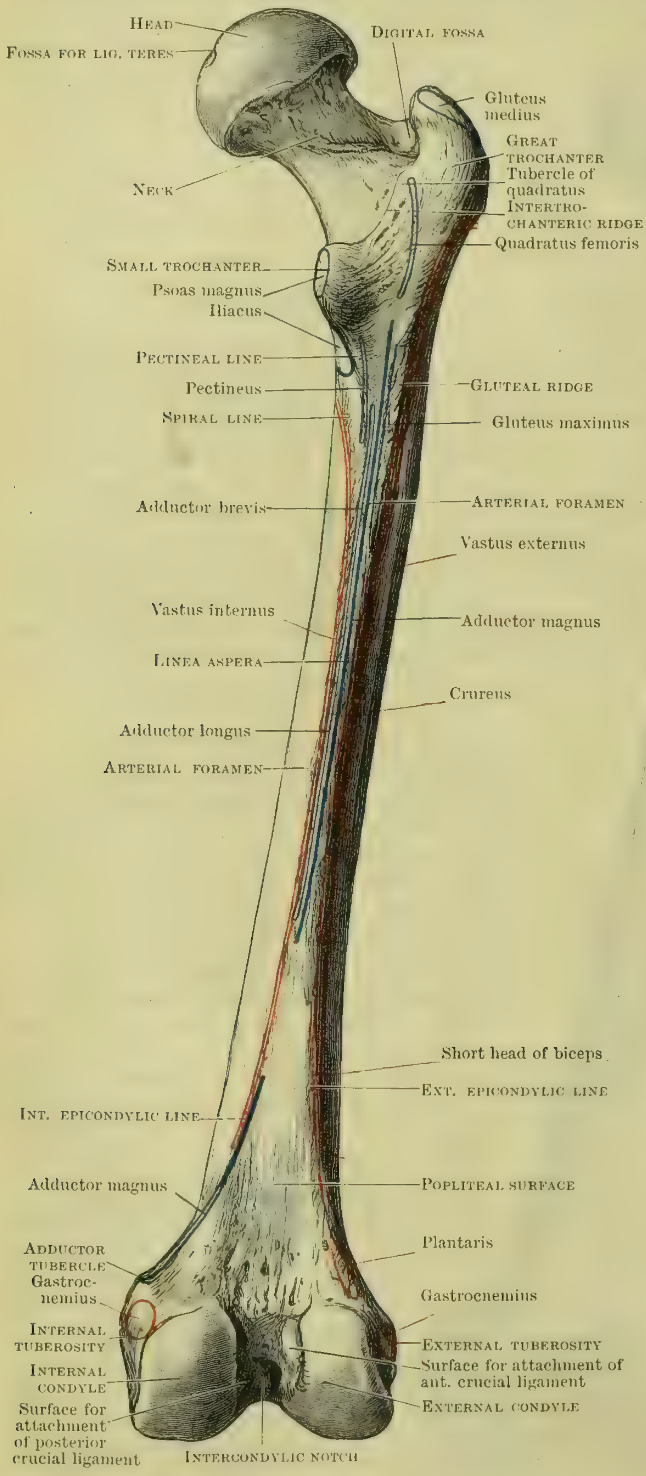


Fig. 161.—Right Femur as seen from Behind.

The **trochanter major** is a large quadrangular process which caps the upper and outer part of the shaft, and overhangs the root of the neck above and behind. Its *outer surface*, of rounded irregular form, slopes upwards and inwards, and is separated from the external surface of the shaft below by a more or less horizontal ridge. Crossing it obliquely from the posterior superior to the anterior

inferior angle is a rough line which serves for the insertion of the gluteus medius muscle; above and below this the surface of the bone is smoother and is overlain by bursæ. The *anterior surface*, somewhat oblong in shape, and inclined obliquely from below upwards and inwards, is elevated from the general aspect of the shaft below, from which it is separated in front by an oblique line leading upwards and inwards to the tubercle at the upper end of the superior part of the spiral line. This surface serves for the insertion of the gluteus minimus. The *superior border* is curved and elevated; into it are inserted the tendons of the obturator internus and gemelli muscles within and in front, and the pyriformis muscle above and behind. The *posterior border* is thick and rounded, and forms the upper part of the posterior intertrochanteric ridge. The angle formed by the superior and posterior borders is sharp and pointed, and forms the tip of the trochanter overhanging the digital fossa, which lies immediately below and within its inner surface.

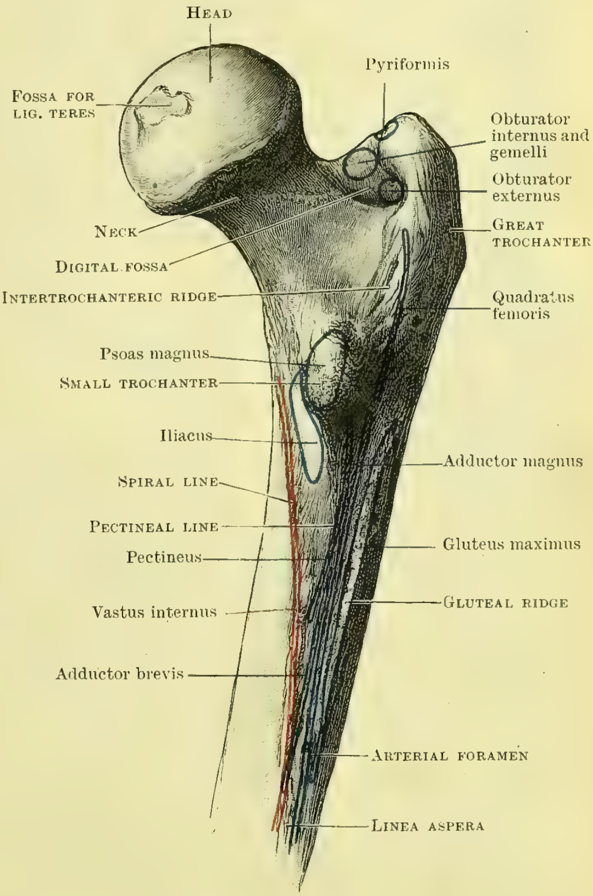


FIG. 162.—BACK VIEW OF UPPER END OF RIGHT FEMUR.

The **trochanter minor** is an elevated pyramidal process situated at the back of the inner and upper part of the shaft where that becomes continuous with the lower and posterior part of the neck. Confluent above with the posterior intertrochanteric ridge, it gradually fades away into the back of the shaft below. The combined tendon of the ilio-psoas is inserted into this process and the bone immediately below it.

The **shaft** (corpus femoris), which is characterised by its great length, is cylindrical in form. As viewed from the front, it is straight or but slightly curved; as seen in profile, it is bent forwards, the curve being most pronounced in its upper part. The shaft is thinnest at some little distance above its middle; below this it gradually increases in width to support the condyles inferiorly; its antero-posterior diameter, however, is not much increased below. Its surfaces are generally smooth and rounded, except behind, where, running longitudinally down the centre of its curved posterior aspect, there is a rough-lipped ridge, the **linea aspera** (linea aspera). Most salient towards the middle of the shaft, the linea aspera consists of an inner lip (labium mediale) and an outer lip (labium laterale), with a narrow intervening rough surface. Above, about 2 to $2\frac{1}{2}$ inches from the trochanter minor, the linea aspera is formed by the convergence of three lines. Of these the outer is a rough, somewhat elevated, ridge, which commences above, on the back of the shaft, external to and on a level with the trochanter minor, and becomes continuous below with the outer lip of the linea aspera. This serves for the bony insertion of the gluteus maximus, and is occasionally developed into an outstanding process called the **trochanter tertius.** Internally the inner lip of the linea aspera is confluent above with a line which winds round the shaft upwards and forwards in front of the trochanter minor to become continuous with the rough ridge which serves to define

the neck from the shaft anteriorly (see *ante*). The whole constitutes what is known as the **spiral line**, and extends from the fore and upper part of the trochanter minor above to the linea aspera below. Intermediate in position between the spiral line in front and internally, and the gluteal ridge externally, there is a third line, the **pectineal line** (linea pectinea), which passes down from the trochanter minor and fades away inferiorly into the surface between the two lips of the linea aspera. Into this the pectineus muscle is inserted. About the junction of the middle with the lower third of the shaft the two lips of the linea aspera separate from one another, each passing in the direction of the condyle of the corresponding side. The lines so formed are called the inner and outer epicondylic lines respectively, and enclose between them a smooth triangular area corresponding to the back of the lower third of the shaft; this, called the **popliteal surface** (planum popliteum), forms the floor of the upper part of the popliteal space. The continuity of the upper part of the internal epicondylic line is but faintly marked, being interrupted by a wide and faint groove along which the popliteal artery passes to enter the space of that name. Below, where the line ends on the upper and inner surface of the internal condyle, there is a little spur of bone called the **adductor tubercle**, to which the tendon of the adductor magnus is attached, and behind which the inner head of the gastrocnemius muscle takes origin.

The **linea aspera** affords extensive linear attachments to many of the muscles of the thigh. The vastus internus arises from the spiral line above and the inner lip of the linea aspera below. The adductor longus is inserted into the inner lip about the middle third of the length of the shaft The adductor magnus is inserted into the intermediate part of the line, extending as high as the level of the trochanter minor, where it lies internal to the insertion of the gluteus maximus. Below, its insertion passes on the internal epicondylic ridge, reaching as low as the adductor tubercle. The adductor brevis muscle is inserted into the linea aspera above, between the pectineus and adductor longus muscles internally and the adductor magnus externally. Below the insertion of the gluteus maximus the short head of the biceps arises from the outer lip as well as from the external epicondylic line ; in front these also serve for the origin of the vastus externus muscle.

The canals for the nutrient arteries of the shaft, which have an upward direction, are usually two in number, and are placed on or near the linea aspera—the upper one about the level of the junction of the middle and upper third of the bone, the lower some three or four inches below—usually on the inner side of the shaft, immediately in front of the inner lip of the linea aspera.

The front and lateral aspects of the shaft are covered by, and furnish surfaces for, the origins of the vasti and crureus muscles.

The **lower extremity** of the femur comprises the two **condyles**. These are two recurved processes of bone, each provided with an articular surface, and separated behind by a deep **intercondylic notch**. United in front, where their combined articular surfaces form an area on which the patella rests, the two condyles differ from each other in the following respects : If the shaft of the bone be held vertically, the **internal condyle** is seen to reach a lower level than the **external**; but, as the femur lies obliquely in the thigh, the condyles are so placed that their inferior surfaces lie in the same horizontal plane. Viewed from below, the internal condyle is seen to be the narrower and shorter of the two. The external condyle is broader, and advances further forward and higher up on the anterior surface of the shaft. The **intercondylic notch** (fossa intercondyloidea) reaches forwards as far as a transverse line drawn through the centre of the external condyle. Its sides are formed by the inner and outer surfaces of the outer and inner condyles respectively, the latter being more deeply excavated, and displaying an oval surface near its lower and anterior part for the attachment of the posterior crucial ligament of the knee-joint. Placed high up, on the posterior part of the inner surface of the external condyle, there is a corresponding surface for the attachment of the anterior crucial ligament. The floor of the notch, which is pierced by numerous vascular canals, slopes upwards and backwards towards the popliteal surface on the back of the shaft, from which it is separated by a slight ridge (linea intercondyloidea) to which the posterior part of the capsule of the knee-joint is attached.

The cutaneous aspect of each condyle (*i.e.* the outer surface of the external condyle and the inner surface of the internal condyle) presents an elevated rough surface, called the **tuberosity** (epicondylus), that of the **internal** (epicondylus medialis) being the more pronounced and outstanding from the line of the shaft; capped above by the adductor tubercle, it affords attachment near its most pro-

minent point to the fibres of the internal lateral ligament of the knee-joint. The **external tuberosity** (epicondylus lateralis), less pronounced and lying more in line with the outer surface of the shaft, is channelled behind by a curved groove—the lower rounded lip of which serves to separate it from the inferior articular surface. This groove ends in front in a pit which is placed just below the most salient point of the tuberosity; hereto is attached the tendon of the popliteus muscle, which overlies the lower lip of the groove in the extended position of the joint, but slips into and occupies the groove when the joint is flexed. Behind the most prominent part of the external tuberosity, and just above the pit for the attachment of the popliteus, the external lateral ligament of the knee-joint is attached, whilst superior to that there is a circumscribed area for the origin of the tendinous part of the outer head of the gastrocnemius muscle.

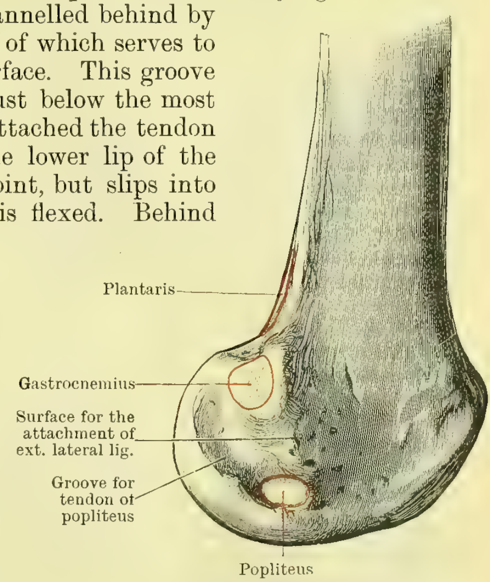


FIG. 163.—LOWER END OF RIGHT FEMUR (Outer Side).

The **articular surface** on the lower extremity is divisible into three parts—that which corresponds to the inferior surface of the shaft and which is formed by the coalescence of the two condyles in front, and those which overlie the under and hinder aspects of each of those processes. The former is separated from the latter by two shallow oblique grooves which traverse the articular surface from before backwards, on either side, in the direction of the anterior part of the intercondylic notch. These furrows are the impressions in which fit the fore-parts of the internal and external semilunar cartilages of the knee-joint respectively when the knee-joint is extended. The anterior articular area or **trochlea** (facies patellaris) is adapted for articulation with the patella. Convex from above downwards, it displays a broad and shallow central groove, bounded on either side by two slightly convex surfaces. Of the two sides, the external is the wider and more prominent and rises on the front of the bone to a higher level than the internal. The **condyloid** or **tibial surfaces** are convex from side to side, and convex from before backwards. Sweeping round the under surface and posterior extremities of the condyles, they describe a spiral curve more open in front than behind. The inner condyloid articular surface is narrower than the outer, and when viewed from below is also seen to describe a curve around a vertical axis. The articular surface of the external condyle is inclined obliquely from before backwards and slightly outwards. The surfaces of the condyles above the articular area posteriorly are confluent superiorly with the popliteal surface of the shaft; from these areas the heads of the gastrocnemius muscles arise. The bone from which the inner head of the muscle springs is often elevated in the form of a tubercle placed on the lower part of the popliteal surface of the shaft, just above the internal condyle. The proportionate length of the femur to the body height is as 1 is to 3·53–3·92.

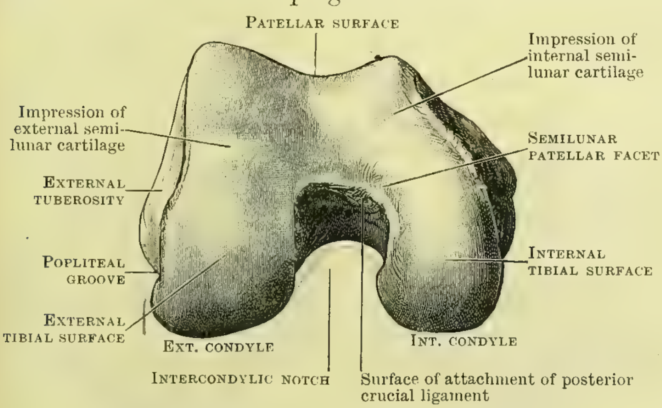


FIG. 164.—LOWER END OF RIGHT FEMUR AS SEEN FROM BELOW.

Arterial Foramina.—Numerous vascular canals are seen in the region of the neck, at the bottom of the digital fossa, on the posterior intercondylic ridge and on the external surface of

the great trochanter. The nutrient arteries for the shaft pierce the bone on or near the linea aspera. Both back and front of the lower end of the shaft display the openings of numerous vascular canals, and the floor of the intercondylic notch is also similarly pierced.

Connexions.—The femur articulates with the os innominatum above and the tibia and patella below. The external surface of the great trochanter determines the point of greatest hip width in the male, being covered only by the skin and superficial fascia and the aponeurotic insertion of the gluteus maximus. In the erect position the tip of the trochanter corresponds to the level of the centre of the hip joint. When the thigh is flexed the trochanter major sinks under cover of the anterior fibres of the gluteus maximus. In women the hip width is usually greatest at some little distance below the trochanter, due to the accumulation of fat in this region. The shaft of the bone is surrounded on all sides by muscles. Its forward curve, however, is accountable to some extent for the fulness of the front of the thigh. The exposed surfaces of the condyles determine to a large extent the form of the knee. In flexion the articular edges can easily be recognised on either side of and below the patella.

Architecture.—The shaft has a medullary cavity which reaches as high as the root of the small trochanter. Inferiorly it extends to within 3½ inches of the lower articular surface. In the upper half the outer compact wall is very thick, but below the middle of the shaft it gradually thins until it reaches the condyles inferiorly, over which it passes as a thin, hardly definable external layer. Above, it is especially thick along the line of the linea aspera, and here the large nutrient canal may be seen passing obliquely upwards in the substance of the dense bone for the space of two inches. In the upper end of the shaft the osseous lamellæ springing from the sides of the medullary cavity arch inwards towards the centre, intersecting each other in a manner comparable to the tracery of a Gothic window. The lower wall of the neck is thick below, near the trochanter minor, but thins rapidly before it reaches the head. From this aspect of the neck there spring a series of oblique lamellæ which pass upwards and inwards, spreading in fan-shaped manner into the under surface of the head. These are intersected above by lamellæ which arch inwards from the outer side of the shaft below the great trochanter, as well as from the under surface of the thin but compact outer shell of the upper surface of the neck, the whole forming a bracket-like arrangement which assists materially in adding to the strength of the neck. Further support is given by the addition of a spur of dense bone which springs from the inner surface of the under side of the neck, just in front of and above the trochanter minor: this is called the **calcar femorale**. From it stout lamellæ having a vertical direction arise. The spongy tissue of the head and great trochanter is finely reticulated, that of the lower part of the neck and upper part of the shaft being more open in its texture. Passing vertically downwards through this tissue there is a vascular canal, the orifice of which opens externally on the floor of the digital fossa.

The spongy tissue of the lower part of the shaft is more delicate and uniform in its arrangement, displaying a more or less parallel striation in a longitudinal direction. Subjacent to the articular surface the tissue is rendered more compact by the addition of lamellæ disposed in curves in harmony with the external aspect of the bone.

Variations.—Absence of the pit on the head of the femur for the attachment of the ligamentum teres has been recorded. This corresponds with the condition met with in the orang. Not infrequently there is an extension of the articular surface of the head on to the fore and upper aspect of the neck; this is a "pressure facet" caused by the contact of the iliac portion of the acetabular margin with the neck of the bone, when the limb is maintained for long periods in the flexed position, as in tailors, and also in those races who habitually squat (Lane, *Journ. Anat. and Physiol.*, vol. xxii. p. 606).

The occurrence of a trochanter tertius has been already referred to. Its presence is not confined to individuals of powerful physique, but may occur in those of slender build, so far suggesting that it is not to be regarded merely as an indication of excessive muscular development. The observations of Dixon (*Journ. Anat. and Physiol.*, vol. xxx. p. 502), who noted the occurrence of a separate epiphysis in three cases in connexion with it, seem to point to its possessing some morphological significance.

Occasionally the gluteal ridge may be replaced by a hollow, the fossa hypotrochanterica, or in some cases the two may co-exist.

The angle of the neck is more open in the child than in the adult, and tends to be less when the femoral length is short and the pelvic width great—conditions which particularly appertain to the female. There is no evidence to show that after growth is completed any alteration takes place in the angle with advancing years (Humphry).

The curvature of the shaft may undergo considerable variations, and the appearance of the posterior surface of the bone may be modified by an absence of the linea aspera, a condition resembling that seen in apes; or by an unusual elevation of the bone which supports the ridge (*fémur à pilastre*), produced, as Manouvrier has suggested, by the excessive development of the muscles here attached.

Under the term "*platymerie*," Manouvrier describes an antero-posterior compression of the upper part of the shaft, frequently met with in the femora of prehistoric races.

Ossification.—The shaft begins to ossify early in the second month of fœtal life, and at birth displays enlargements at both ends, which are capped with cartilage. If the inferior cartilaginous end be sliced away, a small ossific nucleus for the inferior epiphysis will usually be seen. This, as a rule, makes its appearance towards the latter end of the ninth month of fœtal life, and is of service from a medico-legal standpoint in determining the age of the

fœtus. According to Hartman, it is absent in about 12 per cent of children at term, and may appear as early as the eighth month of fœtal life in about 7 per cent. The superior extremity, entirely cartilaginous at birth, comprises the head, neck, and trochanter major. A centre appears for the head during the early part of the first year. That for the trochanter major begins to ossify about the second or third year, whilst the neck is developed as an upward extension of the shaft, which is, however, not confined to the neck alone, but forms the lower circumference of the articular head, as may be seen in bones up to the age of twelve or sixteen; after that, the separate epiphysis of the head begins to overlap it so as to cover it entirely when fusion is complete at the age of eighteen or twenty.

The epiphysis of the great trochanter unites with the shaft and neck about eighteen or nineteen, whilst the epiphysis for the trochanter minor, which usually makes its appearance about the twelfth or thirteenth year, is usually completely fused with the shaft about the age of eighteen. The epiphysis for the lower end, although the first to ossify, is not completely united to the shaft until from about the twentieth to the twenty-second year. It is worthy of note that the line of fusion of the shaft and inferior epiphysis passes through the adductor tubercle, a point which can easily be determined in the living.

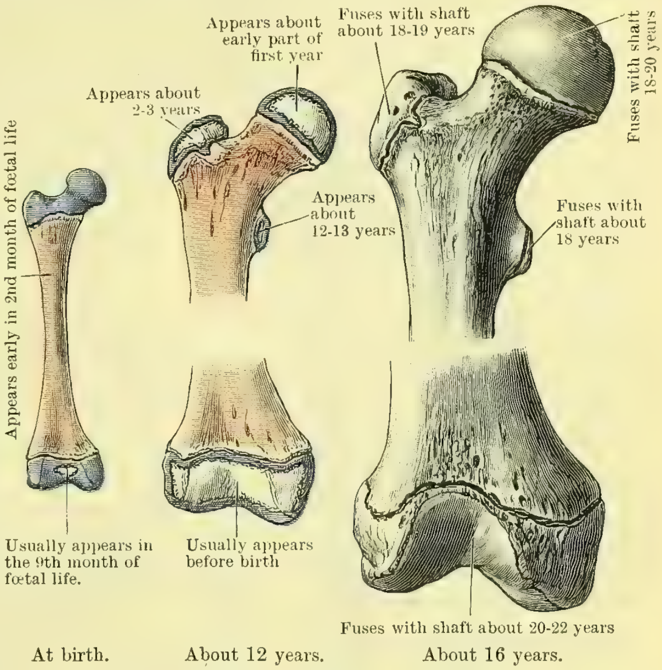


Fig. 165.—Ossification of Femur.

The Patella.

The **patella**, the largest of the sesamoid bones, overlies the front of the knee-joint in the tendon of the quadriceps extensor. Of compressed form and somewhat triangular shape, its lower angle projects downwards and forms a peak, called the **apex** (apex patellæ), whilst its upper edge, or **base** (basis patellæ), broad, thick, and sloping forwards and a little downwards, is divided into two areas by a transverse line or groove; the anterior area so defined serves for the attachment of the common tendon of the quadriceps extensor muscle, whilst the posterior, of compressed triangular shape, is covered by synovial membrane. The *inner* and *outer borders*, of curved outline, receive the insertions of the vastus internus and externus muscles respectively, the

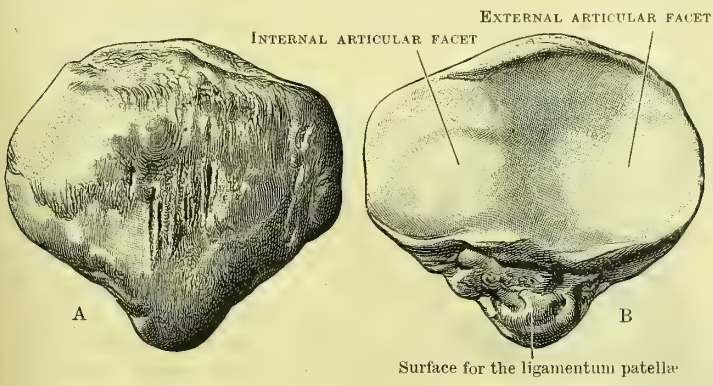


Fig. 166.—Right Patella.
A, Anterior surface. B, Posterior surface.

attachment of the vastus internus being more extensive than that of the vastus externus. The *anterior surface* of the bone, slightly convex in both diameters, has a fibrous appearance, due to its longitudinal striation, and is pierced here and there by the openings of vascular canals. The *posterior* or *femoral articular surface* is divided into two unequal parts (of which the external is the wider) by a vertical elevation which glides in the furrow of the trochlear surface of the femur, and in extreme flexion passes to occupy the intercondylic notch. The outer of the two femoral surfaces is slightly concave in both its diameters; the inner, though slightly concave from above downwards, is usually plane, or somewhat convex transversely. Occasionally, in the macerated bone, indications of a third vertical area are to be noted along the inner edge of the internal aspect. This defines the part of the articular surface which rests on the border of the internal condyle in extreme flexion.

Below the femoral articular area the deep surface of the apex is rough and irregular; the greater part of this is covered by synovial membrane, the ligamentum patellæ being attached to its summit and margins, reaching some little distance round the borders on to the anterior aspect of this part of the bone.

Architecture.—The bone consists of a thick dense layer anteriorly, which thins towards the edges on either side and below; above, it corresponds to the area of insertion of the quadriceps. The femoral articular surface is composed of a layer of compact bone, thickest in correspondence with the vertical elevation. Sandwiched between these two layers is a varying thickness of spongy tissue of fairly close grain, the striation of which on cross section runs in parallel lines from back to front; on vertical section the tissue appears to be arranged in lines passing radially from the deep surface of the femoral area to the more extensive anterior dense plate.

Variations.—Cases of congenital absence of the patella have been recorded.

Ossification.—The patella is laid down in cartilage about the third month of fœtal life. At birth it is cartilaginous, and the tendon of the quadriceps is continuous with the ligamentum patellæ over its anterior surface, and can easily be dissected off. About the third year an ossific centre appears in it and spreads more particularly over its deeper surface. Ossification is usually completed by the age of puberty.

The Tibia.

The **tibia** is the inner bone of the leg. It is much stouter and stronger than its neighbour the fibula, with which it is united above and below. By its superior expanded extremity it supports the condyles of the femur, while inferiorly it shares in the formation of the ankle-joint, articulating with the upper surface and inner side of the astragalus.

The **superior extremity** comprises the **inner** and **outer tuberosities**, the **spine**, and the **tubercle**. Each tuberosity is provided on its upper aspect with an articular surface (facies articularis superior), which supports the corresponding femoral condyle, as well as the interposed semilunar cartilage. Of these two condylic surfaces, the **inner** is the larger; of oval shape, its long axis is placed antero-posteriorly. Slightly concave from before backwards and from side to side, its circumference rises in the form of a sharp and well-defined edge. The **outer condylic surface** is smaller and rounder. Slightly concave from side to side, and gently convex from before backwards, its circumference is well defined in front, but is rounded off behind, thus markedly increasing the convexity of its posterior part.

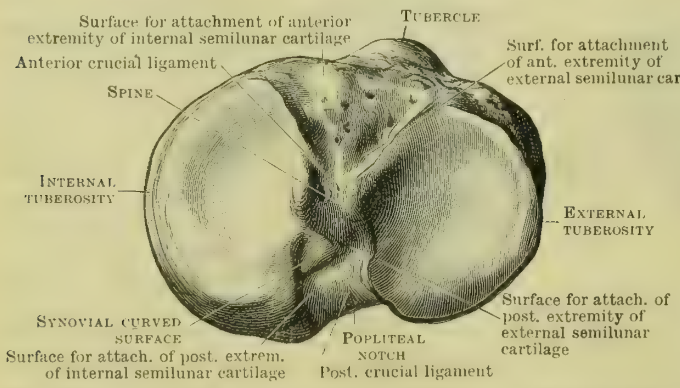


Fig. 167.—Upper Surface of Superior Extremity of Right Tibia.

Between the two condylic surfaces the bone is raised in the centre to form the **spine** (eminentia intercondyloidea), the summit of which is grooved and capped on either side by **tubercles** which spring from and are formed by the upward extension of the neighbouring condylic areas. Of these tubercles the *inner* (tuberculum intercondyloideum mediale) is the higher, and longer in an antero-posterior direction, the *outer* (tuberculum intercondyloideum laterale) being more pointed and not so elevated. In front and behind the spine the articular areas are separated by two irregular V-shaped surfaces, the **intercondylic fossæ.** The **anterior fossa** (fossa intercondyloidea anterior), the larger and wider, furnishes areas for the attachment of the semilunar cartilages on either side, and for the anterior crucial ligament immediately in front of the spine. The floor of this space is pierced by many nutrient foramina. The **posterior intercondylic fossa** (fossa intercondyloidea posterior) is concave from side to side, and slopes downwards and backwards. The external semilunar cartilage is attached near its apex to a surface which rises on to the back of the spine; the internal semilunar cartilage is fixed to a groove which runs along its inner edge, and the posterior crucial ligament derives an attachment from the smooth posterior rounded surface.

The **external tuberosity** (condylus lateralis) is the smaller of the two. It overhangs the shaft to a greater extent than the external, though this is obscured in the living by its articulation with the fibula. The facet for the fibula, often small and indistinct, is placed postero-externally on the under surface of its most projecting part. Antero-externally the imprint caused by the attachment of the ilio-tibial band is often quite distinct. The circumference of the **internal tuberosity** (condylus medialis) is grooved postero-internally for the insertion of the tendon of the semimembranosus.

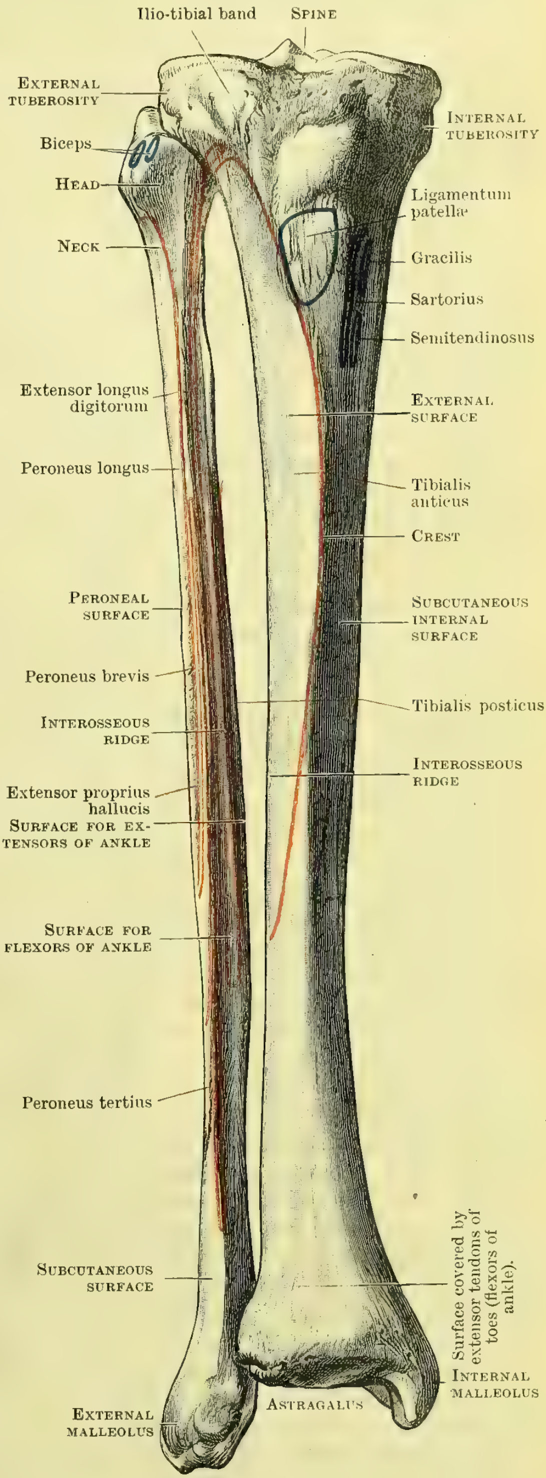


FIG. 168.—RIGHT TIBIA AND FIBULA AS SEEN FROM THE FRONT.

In front of the tuberosities, and about an inch below the level of the condylic surfaces, there is an oval elevation called the **tubercle of the tibia**, or the **anterior tuberosity** (tuberositas tibiæ). The upper half of this is smooth

and covered by a bursa, while the lower part is rough and serves for the attachment of the ligamentum patellæ.

Considered in its entirety, the upper extremity of the tibia is broader transversely than antero-posteriorly, and is inclined backwards so as to overhang the shaft posteriorly.

The **shaft** (corpus tibiæ) is irregularly three-sided. It is narrowest about the junction of its middle and lower thirds, and expands above and below to support the extremities. Running down the front of the bone, there is a gently-curved prominent margin confluent above with the tubercle, but fading away inferiorly on the anterior surface of the lower third of the bone, where it may be traced in the direction of the anterior border of the internal malleolus. This is the **crest** or **shin** (crista anterior), which is subcutaneous throughout its entire length. To the inner side of this is a smooth, slightly convex surface, which reaches as high as the internal tuberosity above, and inferiorly becomes continuous with the inner surface of the internal malleolus. This is the *internal* or *subcutaneous surface* (facies medialis) of the shaft, which is covered only by skin and superficial fascia, except in its upper fourth, where the tendons of the sartorius, gracilis, and semitendinosus muscles overlie it, as they pass towards their insertions. This surface is limited posteriorly by the **internal border** (margo medialis) which passes from the inner and under surface of the internal tuberosity above to the hinder border of the internal malleolus below. This border is rounded and indefinite above and below, being usually best marked about its middle third. To the outer side of the tibial crest is the *external surface* of the bone (facies lateralis); it is limited behind by a straight vertical ridge, the **crista interossea**, to which the interosseous membrane, which occupies the interval between the tibia and the fibula, is attached. This ridge commences above, near the middle of the outer and under surface of the external tuberosity, and terminates below about two inches above the lower extremity by dividing into two lines, which separate and enclose between them the surface for articulation with the lower end of the fibula, and the area of attachment of the inferior interosseous ligament, which here unites the two bones. In its upper two-thirds the external surface provides an extensive origin for the tibialis anticus. Inferiorly, where the tibial crest is no longer well defined, the external surface turns forward on to the front of the shaft, and is limited inferiorly by the anterior margin of the inferior articular surface. Over this the tendon of the tibialis anticus, and the combined fleshy and tendinous parts of the extensor proprius hallucis and extensor communis digitorum muscles pass obliquely downwards. The *posterior surface* (facies posterior) of the shaft lies between the interosseous ridge externally and the internal border on the inner side. Its contours are liable to considerable variation according to the degree of lateral compression of the bone. It is usually full and rounded above, and flat below. Superiorly it is crossed by the **oblique** or **popliteal line** (linea poplitea), which runs downwards and inwards, from the fibular facet above, to the internal border on a level with the junction of the middle with the upper third of the shaft. To this line, as well as to the internal border for some distance below it, the soleus muscle is attached. Into the bulk of the triangular area above it the popliteus muscle is inserted. Arising from the middle of the popliteal line there is a vertical ridge, which passes downwards and divides the posterior aspect of the shaft into two surfaces—an external for the tibial origin of the tibialis posticus muscle, and an internal for the flexor longus digitorum muscle. The inferior third of this surface of the shaft is free from muscular attachments, but is overlain by the tendons of the above muscles, together with that of the flexor longus hallucis. A large nutrient canal, having a downward direction, opens on the posterior surface of the shaft a little below the popliteal line and just external to the vertical ridge which springs from it.

The **inferior extremity** of the tibia displays an expanded quadrangular form. It is furnished with a saddle-shaped articular surface on its under surface (facies articularis inferior), which is concave from before backwards and slightly convex from side to side. This rests upon the superior articular surface of the body of the astragalus, and is bounded in front and behind by well-defined borders. The anterior border is the rounder and thicker, and is oftentimes channelled by a groove

for the attachment of the anterior ligament of the joint; further, it is occasionally provided with a pressure facet caused by the locking of the bone against the neck of the astragalus in extreme flexion. Externally the edge of the articular area corresponds to the base of the triangle formed by the splitting of the interosseous ridge into two parts. Where these two lines join it, both in front and behind, the bone is elevated into the form of tubercles, in the hollow between which (incisura fibularis) the lower end of the fibula is lodged, being held in position by powerful ligaments. The cartilage-covered surface occasionally extends for some little distance above the base of the triangle. Internally there is a down-projecting process, called the **internal malleolus** (malleolus medialis), the inner aspect of which is subcutaneous and forms the projection of the inner ankle. Its external surface is furnished with a pyriform facet (facies articularis malleolaris), confluent above with the cartilage-covered area on the inferior extremity of the shaft; this articulates with a corresponding area on the inner surface of the body of the astragalus. Inferiorly the malleolus is pointed in front, but notched behind for the attachment of the internal lateral ligament of the ankle. Running obliquely along the posterior surface of the malleolus there is a broad groove (sulcus malleolaris) in which the tendons of the tibialis posticus and flexor longus digitorum muscles are lodged; whilst a little to the fibular side of this, and running downwards over the posterior surface of the lower extremity of the bone, there is another groove, often faintly marked, for the lodgment of the tendon of the flexor longus hallucis muscle. The proportionate length of the tibia to the body height is as 1 is to 4·32–4·80.

Arterial Foramina.—Nutrient canals are seen piercing the upper extremity of the bone around its circumference and above the tubercle. The floors of the intercondylic fossæ are also similarly pierced, and there is usually a canal of large size opening on the summit of the spine. Two or three foramina of fair size are seen running upwards into the substance of the bone a little below and to the inner side of the tubercle, while the principal vessel for the shaft passes downwards into the bone on its posterior surface, about the level of the junction of the upper and middle thirds. The inner surface of the internal malleolus, as well as the anterior and posterior borders of the inferior extremity, are likewise pitted by the orifices of small vascular channels.

Connexions.—Superiorly the tibia supports the condyles of the femur, and is connected in front with the patella by means of the patellar ligament. Articulating externally with the fibula above and below, it is united to that bone throughout nearly its entire length by the interosseous membrane. The crest and internal surface can be readily examined, as they are subcutaneous, except above where the internal surface is overlain by the thin tendinous aponeurosis of the muscles passing over the inner side of the knee. The form of the lower part of the knee in front is determined by the tuberosities on either side crossed mesially by the ligamentum patellæ. Inferiorly the internal malleolus forms the projection of the inner ankle, which is wider, not so low, less pointed, and placed in advance of the projection of the outer ankle. The front and back of the lower end of the bone are crossed by tendons, which mask to a certain extent its form.

Architecture.—The shaft of the bone is remarkable for the thickness and density of the osseous tissue which underlies the crest. The posterior wall is stout, but the internal and external walls are thinner. The several walls are thickest opposite the middle of the shaft, and thin out above and below where the shaft unites with the epiphyses. The medullary canal, narrow and circular in the middle of the bone, increases in all its diameters above and below, and reaches to within $2\frac{1}{2}$ to 3 inches of either extremity. Superiorly the arrangement of the lamellæ of the spongy tissue resembles a series of arches springing from the dense outer walls. These form a platform on which the superior epiphysis rests, the spongy tissue of which displays a more or less vertical striation. This is much more compact under the condylic surfaces, the superficial aspect of which is formed by a thin layer of dense bone. The spine and tubercle are also formed of compact tissue, whilst the circumference of the tuberosities is covered by a thinner and less dense wall. In the lower end of the shaft the spongy tissue, of a loose and cellular character, is arranged in vertical fibres, blending inferiorly with the closer tissue of the inferior epiphysis, the articular surface of which is covered by a thin but dense layer.

In the adult bone the nutrient canal for the shaft is embedded in the dense posterior wall for the space of two inches.

Variations.—The tibia is often unduly laterally compressed, leading to an increase in its antero-posterior diameter as compared with its transverse width. This condition is more commonly met with in the bones of prehistoric and savage races than in modern Europeans. Attention was first directed to this particular form by Busk, who named the condition **platycnemia**. The general appearance of such tibiæ resembles that seen in the apes, and depends on an exceptional development of the tibialis posticus muscle, though, as Manouvrier has pointed out, in apes this is associated with the direct action of the muscle on the foot, as in climbing, whereas in man, as a consequence of the bipedal mode of progression, the muscle is employed in an inverse sense, viz. by steadying the tibia on the foot, and thus providing a fixed

base on which the femur can move. Such platycnemic tibiæ are occasionally met with in the more highly civilised races, and are, according to Manouvrier, associated with habits of great activity among the inhabitants of rough and mountainous districts.

Another interesting condition is one in which the upper extremity is more strongly recurved than is usual. This retroversion of the head of the tibia was at one time supposed to represent an intermediate condition in which the knee could not be fully extended so as to bring the axis of the leg in line with the thigh; but such opinion has now been upset by the researches of Manouvrier, who claims that it is the outcome of a habit not uncommon amongst peasants and countrymen, viz. that of walking habitually with the knees slightly bent.

Habitual posture also leaves its impress on the form of the tibia, and in races in which the use of the chair is unknown, the extreme degree of flexion of the knee and ankle necessitated by the adoption of the squatting position as an attitude of habitual rest is associated with an increase in the convexity of the external condylic surface, and the appearance, not infrequently, of a pressure facet on the anterior border of the lower extremity, which rests in that position on the neck of the astragalus. Cases of congenital absence of the tibia have been frequently described, amongst the most recent being those recorded by Clutton, Joachimsthal, Bland Sutton, and Waitz.

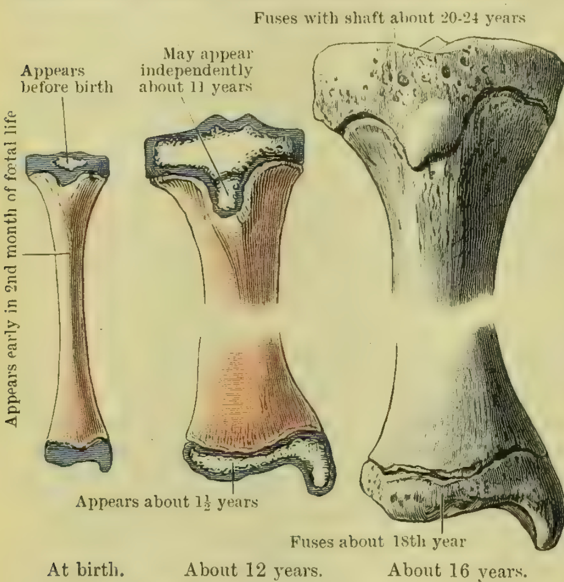


Fig. 169.—Ossification of the Tibia.

Ossification.—The shaft begins to ossify early in the second month of intra-uterine life. At birth it is well formed, and capped above and below by pieces of cartilage, in the upper of which the centre for the superior epiphysis has already usually made its appearance. From this the tuberosities and tubercle are developed, though sometimes an independent centre for the latter appears about the eleventh or twelfth years, rapidly joining with the already well-developed mass of the rest of the epiphysis. Complete fusion between the superior epiphysis and the shaft does not take place until the twentieth or the twenty-fourth year. The centre for the lower articular surface and the internal malleolus makes its appearance about the end of the second year, and union with the shaft is usually complete by the age of eighteen. Lambertz notes the occasional presence of an accessory nucleus in the malleolus.

The Fibula.

The **fibula**, or **peroneal bone**, is a slender bone with two enlarged ends. It lies to the outer side of the tibia, with which it is firmly united by ligaments, and nearly equals that bone in length.

The first difficulty which the student has to overcome is to determine which is the upper and which the lower extremity of the bone. This can easily be done by recognising the fact that there is a deep pit on the inner aspect of the lower extremity immediately behind the triangular articular surface. Holding the bone vertically with the lower extremity downwards and so turned that the triangular articular area lies in front of the notch already spoken of, the subcutaneous non-articular aspect of the inferior extremity will point to the side to which the bone belongs.

The **superior extremity** or **head** of the fibula (capitulum fibulæ), of irregular rounded form, is bevelled on its inner surface so as to adapt it to the form of the under surface of the external tuberosity of the tibia. At the border, where this surface becomes confluent with the outer aspect of the head, there is a pointed upstanding eminence called the **styloid process** (apex capituli fibulæ); to this the short external lateral ligament is attached, as well as a piece of the tendon of the biceps, which is inserted into its fore-part. Immediately to the inner side of this, and occupying the summit of the internal sloping surface, there is an **articular area** (facies articularis capituli), of variable size and more or less triangular shape. This

serves for articulation with the external tuberosity of the tibia. The long external lateral ligament, together with the remainder of the tendon of the biceps muscle which surrounds it, is attached to the outer and upper side of the head in front of the styloid process. In front and behind the head there are usually prominent tubercles. The anterior of these is associated with the origin of the peroneus longus muscle; the posterior, whilst furnishing an origin for the upper fibres of the soleus, serves to deepen the groove, behind the superior tibio-fibular articulation, in which the tendon and fleshy part of the popliteus muscle play. The constricted portion of the shaft below the head is often referred to as the **neck**; around the outer side of this the external popliteal nerve winds.

The **shaft** of the fibula (corpus fibulæ) presents many varieties of shape and form, being ridged and channelled in such a way as greatly to increase the difficulties of the student in recognising the various surfaces described. The most important point is first to determine the position of the interosseous ridge. Holding the bone in the position which it normally occupies in the leg, it will be noticed that the external surface of the lower extremity is limited in front and behind by two lines, which, converging above, enclose between them a triangular subcutaneous area which lies immediately above the outer ankle. From the summit of the triangle so formed a well-defined ridge may be traced up the front of the shaft to reach the anterior aspect of the head. This is the *anterior border*, and must not be mistaken for the interosseous ridge, which is now easy to find, for the next ridge which lies immediately internal to the anterior border, or towards the tibial side on the anterior aspect of the bone, is the line to which the interosseous membrane is attached. As a rule these two lines are separated by a considerable interval in the lower half of the bone, but tend to run much closer together above; indeed it is not uncommon to find that they coalesce to form a single crest. Let it therefore be clear that the interosseous line is that which lies immediately

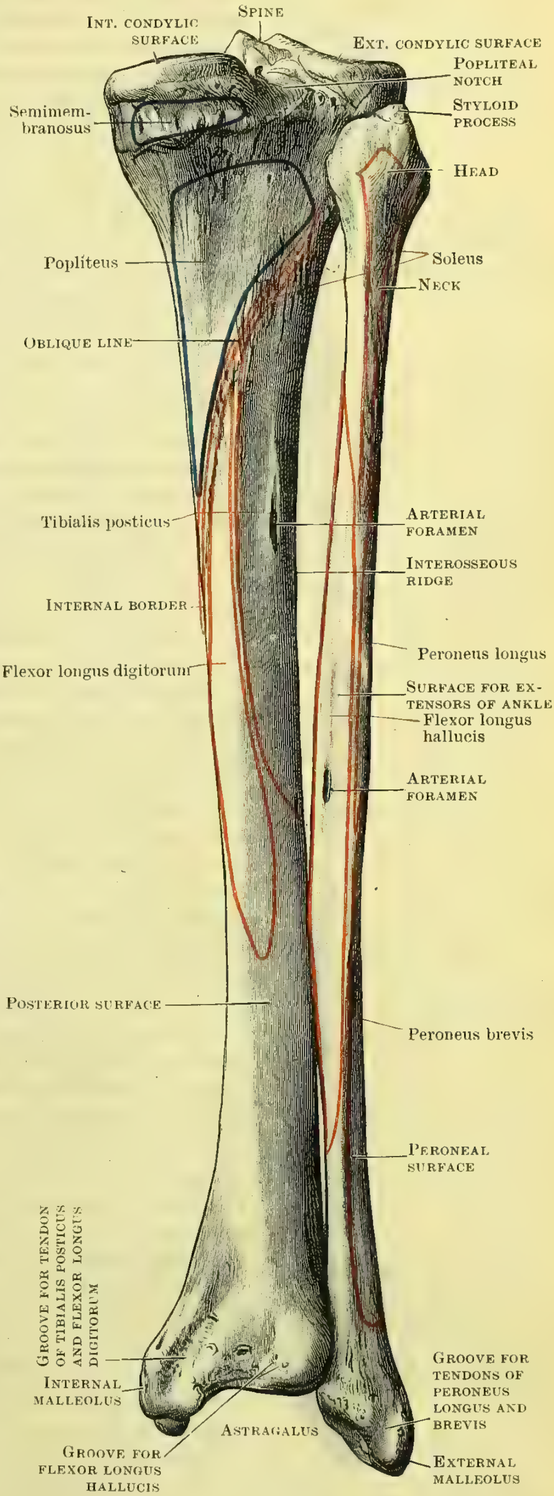


Fig. 170.—Right Tibia and Fibula as seen from Behind.

internal to the ridge which springs inferiorly from the malleolar subcutaneous triangular surface, notwithstanding the differences in width of the surface which separates the lines, or their occasional coalescence above.

The position of the interosseous ridge enables us at once to separate the flexor aspect of the bone from its extensor surface, using these terms in relation to the movements of the ankle.

The use of these terms is not, strictly speaking, correct, and they are here used in a physiological and not in a morphological sense. The anterior surface of the leg is the true extensor surface and is comparable with the posterior surface of the forearm, the change in position having been brought about developmentally by difference in the rotation of the limbs. Flexion of the ankle, so called, is in reality an extensor movement, and corresponds to extension at the wrist; see Humphry, *Journ. Anat. and Physiol.*, vol. xxviii. p. 15.

In addition, there is the peroneal surface, which corresponds to the outer side of the shaft. Starting then at the interosseous ridge, and passing forwards round the outer side of the shaft, the **flexor surface** is the first met with; this is bounded externally by the anterior border, and, as has been said, may be either of considerable width or almost linear. From this arises the extensor communis digitorum, together with the peroneus tertius and the extensor proprius hallucis muscles, which, though extensors of the toes, are also *flexors* of the ankle.

The *anterior border* serves for the attachment of the intermuscular septum, which separates the foregoing group of muscles from that which lies along the outer side of the shaft, viz. the peroneus longus and brevis muscles. The surface from which these arise is limited behind by the *posterior border*, which is usually sharp and well defined below, where it is continuous with the bone immediately above the pit on the inner surface of the lower extremity, whilst it tends to be less distinct and more rounded above where it runs into the base of the styloid process. In its upper third or fourth this border is often rough and tubercular where it serves for the origin of the soleus. The **outer** or **peroneal surface** is somewhat twisted, being directed rather forwards above, but tending to turn backwards below where it becomes continuous with the groove which courses along the back of the external malleolus and which lodges the tendons of the peroneus longus and brevis muscles. The remainder of the shaft, included between the posterior border behind and the interosseous ridge in front and internally, is the **extensor surface**, for here arise the several muscles whose action in part is to extend the ankle. This surface is cut up by a curved ridge often the most prominent and outstanding on the bone, and hence frequently mistaken by the student for the interosseous ridge; it serves to define the area for the origin of the tibialis posticus, and arises below from the posterior border of the interosseous ridge at the junction of the middle and inferior thirds of the shaft, curves a little backwards, and passing upwards and obliquely forwards again joins the interosseous ridge once more in the region of the neck. This is oftentimes called the internal border (crista medialis); and the surface so mapped off, the internal surface. The ridge itself serves for the attachment

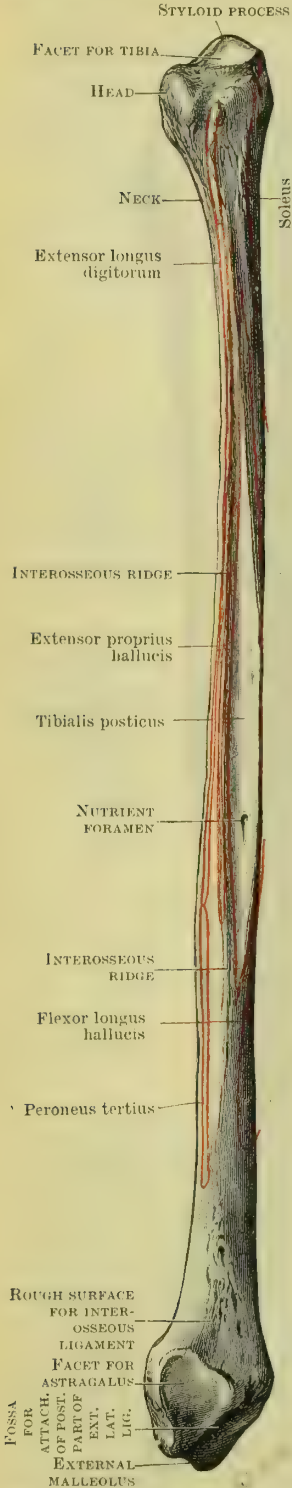


FIG. 171.—RIGHT FIBULA AS SEEN FROM THE INNER SIDE.

of the aponeurosis which covers the tibialis posticus muscle. The remainder of the extensor aspect of the shaft, which, above, is directed backwards, is so twisted that inferiorly it is directed inwards. From this, in its upper part, the soleus muscle arises; whilst lower down, the flexor longus hallucis muscle derives an extensive origin. Both of these muscles, together with the tibialis posticus, act as *extensors* of the ankle. On this aspect of the bone, at or near the middle of the shaft, and just behind the prominent tibial ridge, is the opening of the nutrient canal, which has a downward direction.

The **inferior extremity** of the fibula, or **external malleolus** (malleolus lateralis), is of pyramidal form. Its inner surface is furnished with a triangular articular area (facies articularis melleoli), plane from before backwards, and slightly convex from above downwards, which articulates with a corresponding surface on the outer side of the body of the astragalus. Behind this there is a deep pit, to which the posterior fasciculus of the external lateral ligament is attached. Above the articular facet there is a rough triangular area on the extensor surface of the shaft, from the summit of which the interosseous ridge arises; hereto are attached the strong fibres of the inferior interosseous ligament which bind together the opposed surfaces of the tibia and fibula. The external surface of the inferior extremity forms the elevation of the external malleolus which determines the shape of the projection of the outer ankle. Rounded from side to side and from above downwards, it terminates below in a pointed process, which reaches a lower level than the corresponding process of the tibia, from which it also differs in being narrower and more pointed and being placed in a plane nearer the heel. Superiorly, this surface, which is subcutaneous, is continuous with the triangular subcutaneous area so clearly defined by the convergence above of the lines which unite to form the anterior border. The anterior border and tip of the external malleolus furnish attachments to the anterior and middle bands of the external lateral ligament of the ankle. The posterior surface of the external malleolus, broad above, where it is confluent with the peroneal or external surface, is reduced in width below by the presence of the pit which lies to its inner side. This aspect of the bone is grooved (sulcus malleolaris) by the tendons of the peroneus longus and brevis muscles, which curve round the posterior and lower-pointed aspect of the malleolus. The proportionate length of the fibula to the body height is as 1 is to 4·37–4·82.

Arterial Foramina.—Numerous minute vascular canals are seen piercing the outer surface of the head, and one or two of larger size are seen on the inner surface immediately in front of the superior articular facet. The canal for the nutrient artery of the shaft, which has a downward direction, is situated on the back of the bone about its middle. The outer surface of the external malleolus displays the openings of many small canals, and one or two larger openings are to be noted at the bottom of the pit behind the inferior articular surface.

Connexions.—The head and external malleolus, and part of the shaft immediately above the latter, are subcutaneous. The remainder of the shaft is covered on all sides by the muscles which surround it. Superiorly the bone plays no part in the formation of the knee-joint, but inferiorly assists materially in strengthening the ankle-joint by its union with the tibia and its articulation with the astragalus. In position the bone is not parallel to the axis of the tibia, but oblique to it, its upper extremity lying posterior and external to a vertical line passing through the external malleolus.

Architecture.—A medullary canal runs throughout the length of the shaft, reaching as high as the neck above, and extending as low as a point about 2½ inches above the inferior extremity of the external malleolus. The outer wall of the shaft is usually considerably thicker than the inner. The head is formed of loose cellular bone, enclosed within a very thin dense envelope. The spongy tissue of the lower extremity is more compact, and acquires considerable density on the surfaces underlying the articular area and the pit behind it. The canal for the nutrient artery of the shaft opens into the medullary cavity about an inch below its external aperture.

Ossification.—The shaft begins to ossify about the middle of the second month of fœtal life. At the end of the third month there is but little difference in size between it and the tibia, and at birth the fibula is much larger in proportion to the size of the tibia than in the adult. Its extremities are cartilaginous, the lower extremity not being as long as the internal malleolar cartilage of the tibia. It is in this, however, that an ossific centre first appears about the end of the second year, which increases rapidly in size, and unites with the shaft about nineteen years. The centre for the superior epiphysis begins to

ossify about the third or fourth year, and union with the shaft is not complete until a period somewhat later than that for the inferior epiphysis. The mode of ossification of the lower extremity is an exception to the general rule that epiphyses which are the first to ossify are the last to unite with the shaft.

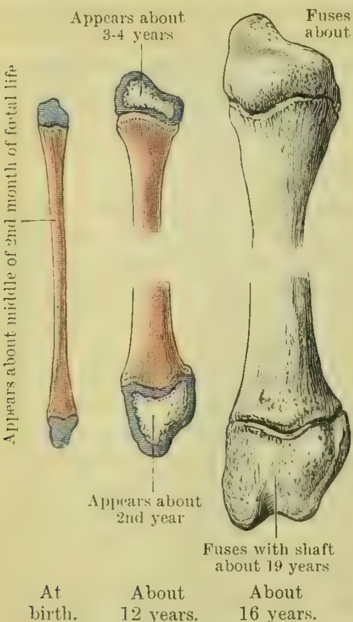


FIG. 172.—OSSIFICATION OF FIBULA.

In its earlier stages of development it has been stated, on the authority of Leboucq, Gegenbauer, and others, that the fibula as well as the tibia is in contact with the femur. This is, however, denied by Grunbaum ("Proc. Anat. Soc.," *Journ. Anat. and Physiol.*, vol. xxvi. p. 22), who states that after the sixth week the fibula is not in contact with the femur, and that prior to that date it is impossible to differentiate the tissue which is to form femur from that which forms fibula.

Variations.—The fibula may be ridged and grooved in a remarkable manner, as is the case in many bones of prehistoric races. This is probably associated with a greater or perhaps more active development of the muscles attached to it.

The superior articular facet varies much in size. Bennett (*Dublin Journ. Med. Sc.*, Aug. 1891) records a case in which it was double, and also notes the occurrence of specimens in which it was absent and in which the head of the bone did not reach as high as the tibial tuberosity.

Many instances of partial or complete absence of the bone have been published. (Lefèbre, P., *Contribution à l'étude de l'absence congénitale du péroné.* Lille. 1895.)

BONES OF THE FOOT.

The bones of the foot, twenty-six in number, are arranged in three groups: the tarsal, seven in number; the metatarsal, five in number; the phalanges, fourteen in number.

Comparing the foot with the hand, the student will be struck with the great proportionate size of the tarsus as compared with the carpus, and the reduction in size of the bones of the toes as compared with the fingers. The size of the metatarsal segment more nearly equals that of the metacarpus.

THE TARSUS.

The **tarsus** (ossa tarsi) consists of seven bones—the astragalus, os calcis, navicular or scaphoid, three cuneiforms, and the cuboid. Of irregular form and varying size, they may be described as roughly cubical, presenting for examination dorsal and plantar surfaces as well as anterior, posterior, internal, and external aspects.

THE ASTRAGALUS.

The **astragalus** (talus) is the bone through which the body weight is transmitted from the leg above to the foot below. Superiorly the tibia rests upon it, whilst on either side it articulates with the internal and external malleolar processes of the tibia and fibula respectively; inferiorly it overlies the os calcis, and anteriorly it articulates with the navicular. For descriptive purposes the bone is divisible into two parts—the **body** (corpus tali) blended in front with the **neck** (collum tali), which supports the **head** (caput tali).

The *upper surface* of the **body** is provided with a saddle-shaped articular surface (trochlea tali), broader in front than behind, for articulation with the under surface of the tibia. The inner edge of the trochlea is straight; whilst the outer border, which is sharp in front and more rounded behind, is curved inwards posteriorly, where it is bevelled to form a narrow, elongated, triangular facet, which is in contact with the transverse or inferior tibio-fibular ligament during flexion of the ankle

(Fawcett, *Ed. Med. Journ.*, 1895). Over the external border the cartilage-covered surface is continuous externally with an extensive area of the form of a quadrant. This is concave from above downwards, and articulates with the inner surface of the fibular malleolus. Its inferior angle is prominent and somewhat everted, and sometimes referred to as the **external process** (processus lateralis tali). The inner aspect of the body has a comma-shaped facet, confluent with the superior articular surface, over the inner edge of the trochlea; this articulates with the outer surface of the tibial malleolus. Inferior to this the bone is rough and pitted by numerous small openings, and just below the tail of the comma there is a circular impression for the attachment of the deep fibres of the internal lateral ligament. On the *inferior surface* there is a deep concave facet, called the **posterior calcanean facet** (facies calcanea articularis posterior), which is of more or less oval or oblong form and is placed obliquely from behind forwards and outwards; this rests upon a corresponding surface on the upper aspect of the os calcis. In front of this, and crossing the bone from within outwards and forwards, is a deep **furrow** (sulcus tali), the floor of which is pierced by numerous large canals. It serves for the attachment of the strong interosseous ligament which unites the astragalus with the os calcis, and separates the facet already described from a smaller oval articular surface having a slightly convex surface, which lies immediately in front of it. This is called the **middle calcanean facet** (facies articularis calcanea media), and articulates with the upper surface of the sustentaculum tali of the os calcis. Posteriorly the body is provided with two tubercles, separated by a groove; the external of these (processus posterior tali) is usually the larger

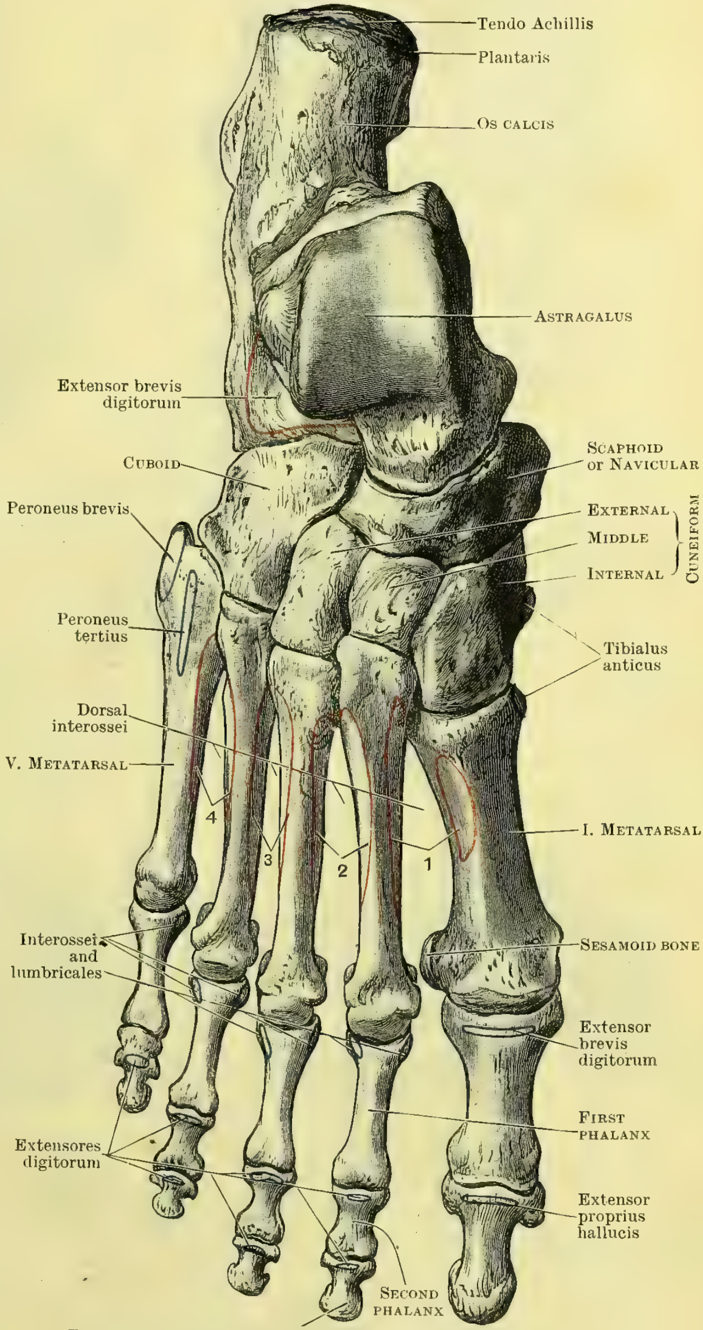


Fig. 173.—Bones of the Right Foot as seen from Above.

and is occasionally a separate ossicle (os trigonum). To it is attached the posterior fasciculus of the external lateral ligament of the ankle-joint. The groove, which winds obliquely from above downwards and inwards over the posterior surface of the bone, lodges the tendon of the flexor longus hallucis muscle.

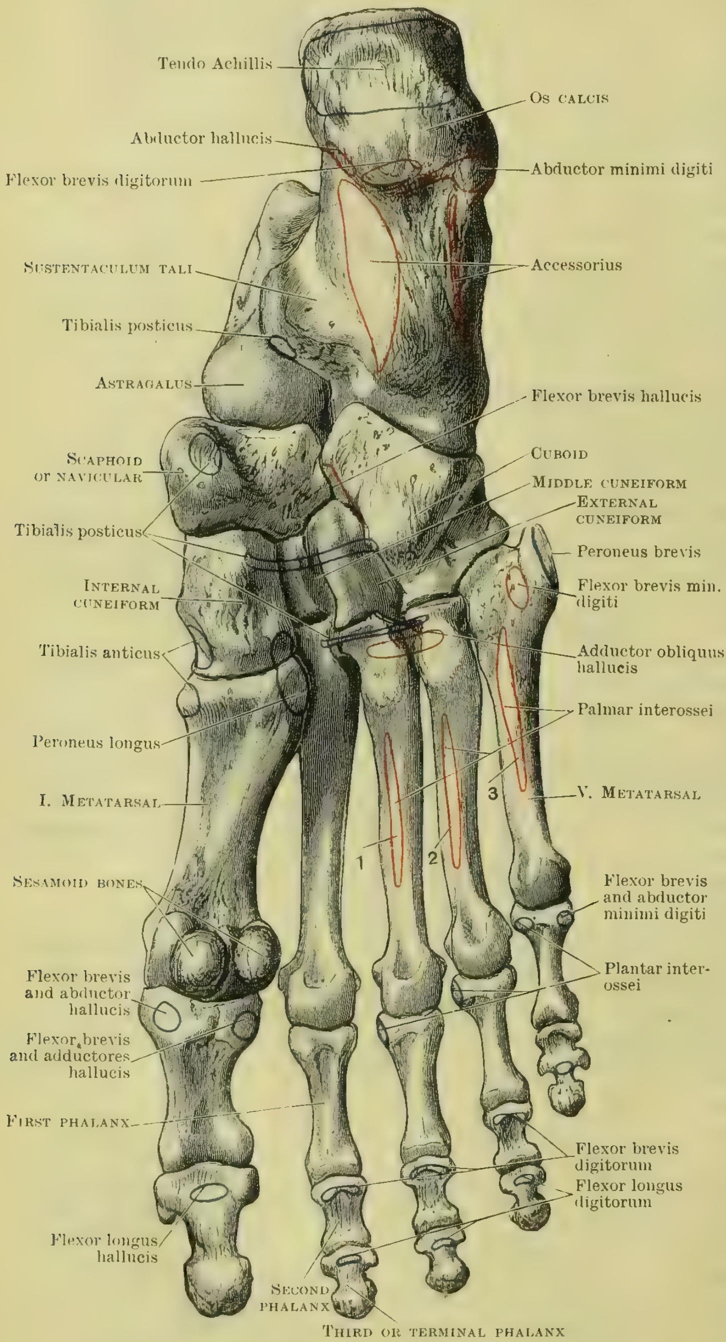
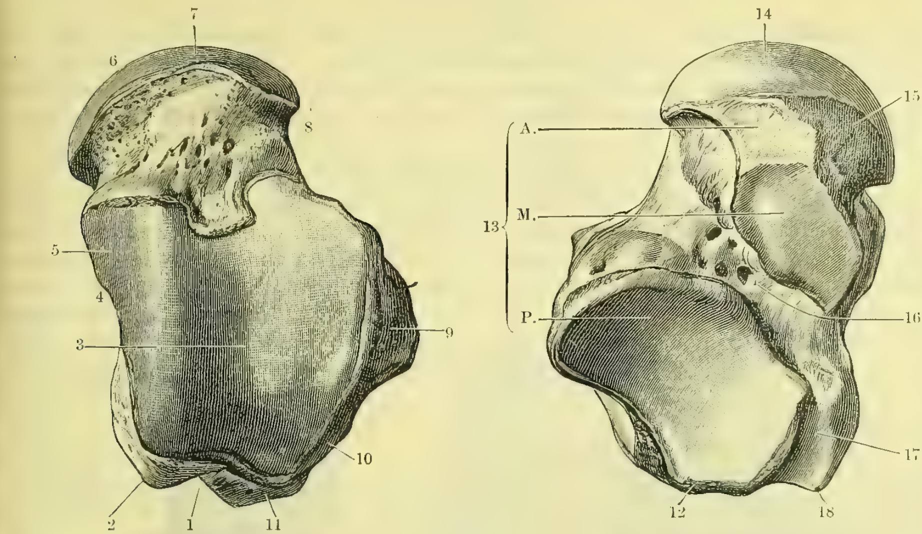


Fig. 174.—Bones of the Right Foot as seen from Below.

The **head** (caput tali), of oval form, is directed forwards and inwards. Its anterior surface is convex from side to side and from above downwards, and articulates with the navicular bone (facies articularis navicularis). Inferiorly this surface is confluent with the middle calcanean facet, but in well-marked specimens, or when the bones are articulated, it will be seen that a small area in front of, and external to, the middle calcanean facet, rests upon an articular surface on the upper part of the fore portion of the os calcis, and is called the **anterior calcanean facet** (facies articularis calcanea anterior). To the inner and under surface of the head there is a cartilage-covered surface which does not articulate with any bone, but rests on the upper surface of the inferior calcaneo-navicular ligament, and is supported on the inner side by the tendon of the tibialis posticus muscle (Fawcett, *Ed. Med. Journ.* 1895, p. 987).

The **neck** (collum tali), best seen above, passes from the front of the body and inclines towards the inner side. It is confluent with the inner surface in front of the internal malleolar facet, and externally forms a wide groove, which becomes continuous inferiorly with the outer end of the interosseous groove.

Variations.—The anterior is sometimes separated from the middle calcanean facet by a non-articular furrow. The posterior external tubercle, often largely developed, is occasionally (2·7



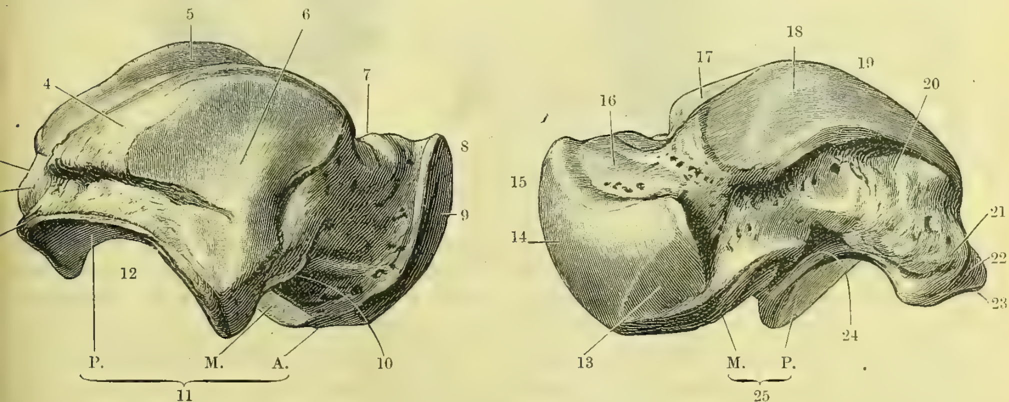
A B

FIG. 175.—THE RIGHT ASTRAGALUS.

A, Upper Surface. B, Under Surface.

1. GROOVE FOR FLEX. LONG. HALLUCIS.
2. INTERNAL TUBERCLE.
3. TROCHLEAR SURFACE FOR TIBIA.
4. BODY.
5. FOR ARTICULATION WITH INTERNAL MALLEOLUS.
6. HEAD.
7. FOR ARTICULATION WITH NAVICULAR.
8. NECK.
9. FOR ARTICULATION WITH EXTERNAL MALLEOLUS.
10. SURFACE AGAINST WHICH THE INFERIOR TIBIO-FIBULAR LIGAMENT RESTS.
11. EXTERNAL TUBERCLE.
12. EXTERNAL TUBERCLE.
13. POSTERIOR, MIDDLE, AND ANTERIOR FACETS FOR OS CALCIS.
14. FOR ARTICULATION WITH NAVICULAR.
15. SURFACE RESTING ON INFERIOR CALCANEO-NAVICULAR LIGAMENT.
16. INTEROSSEOUS GROOVE.
17. INTERNAL TUBERCLE.
18. GROOVE FOR FLEXOR LONGUS HALLUCIS.

per cent) a separate ossicle forming what is known as the os trigonum (Bardeleben); or it may be united to the body of the astragalus by a distinct synchondrosis. A smooth articular surface may occasionally be found on the outer side of the upper surface of the neck. This is a pressure facet



A B

FIG. 176.—THE RIGHT ASTRAGALUS.

A, As seen from the Outer Side. B, As seen from the Inner Side.

1. EXTERNAL TUBERCLE.
2. GROOVE FOR FLEXOR LONGUS HALLUCIS.
3. INTERNAL TUBERCLE.
4. SURFACE AGAINST WHICH THE INFERIOR TIBIO-FIBULAR LIGAMENT RESTS.
5. TROCHLEA FOR TIBIA.
6. FOR ARTICULATION WITH EXTERNAL MALLEOLUS.
7. NECK. 8. HEAD.
9. FOR ARTICULATION WITH NAVICULAR.
10. INTEROSSEOUS GROOVE.
11. ANTERIOR, MIDDLE, AND POSTERIOR FACETS FOR OS CALCIS.
12. BODY.
13. SURFACE RESTING ON INTERNAL CALCANEO-NAVICULAR LIGAMENT.
14. FOR ARTICULATION WITH NAVICULAR.
15. HEAD.
16. NECK.
17. TROCHLEA FOR TIBIA.
18. FOR ARTICULATION WITH INTERNAL MALLEOLUS.
19. BODY.
20. IMPRESSION FOR INTERNAL LATERAL LIGAMENT.
21. INTERNAL TUBERCLE.
22. GROOVE FOR FLEXOR LONGUS HALLUCIS.
23. EXTERNAL TUBERCLE.
24. INTEROSSEOUS GROOVE.
25. POSTERIOR AND MIDDLE FACETS FOR OS CALCIS.

dependent on the frequent use of the ankle-joint in a condition of extreme flexion, and is caused by the opposition of the bone against the anterior edge of the lower end of the tibia.

The Os Calcis.

The **os calcis** (calcaneus) is the largest of the tarsal bones. It supports the astragalus above and articulates with the cuboid in front. Inferiorly and behind, its posterior extremity or tuberosity forms the heel on which so large a proportion of the body weight rests. The long axis of the bone inclines forwards and a little outwards.

The *upper surface* of the os calcis is divisible into two parts—a posterior non-articular part and an anterior articular portion. The length of the former varies according to the projection of the heel; rounded from side to side, it is slightly concave from before backwards. In front of this there is a convex articular area of variable shape (facies articularis posterior), sometimes nearly circular, at other times oval and occasionally almost triangular. This is directed upwards and forwards, and articulates with the posterior calcanean facet on the under surface of the astragalus. Anterior to this facet the bone is deeply excavated, forming a fossa from

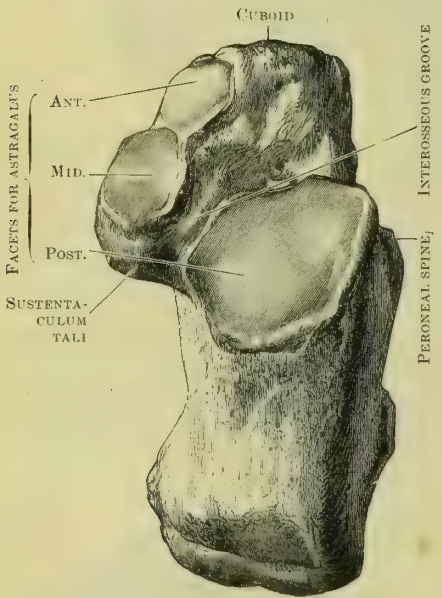


Fig. 177.—The Right Os Calcis as seen from Above.

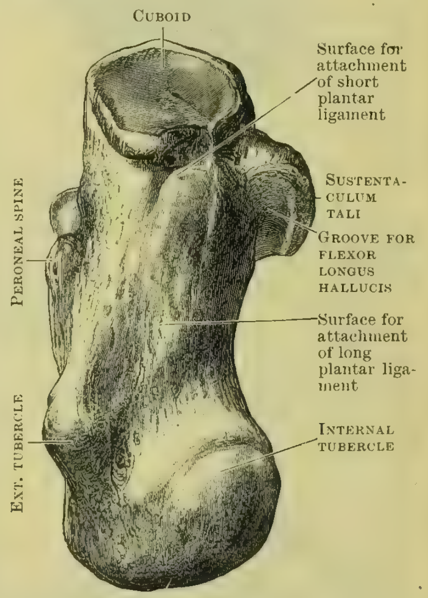


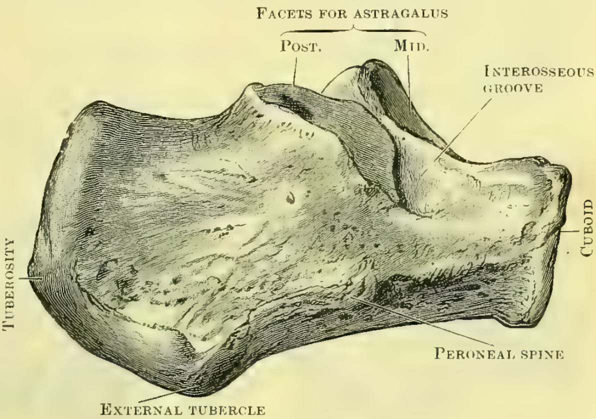
Fig. 178.—The Right Os Calcis as seen from Below.

which a **groove** (sulcus calcanei) leads backwards and inwards around the antero-internal border of the articular surface. When the os calcis is placed in contact with the astragalus, this groove coincides with the sulcus on the under surface of the latter bone and so forms a **canal** or tunnel (sinus tarsi), in which the strong interosseous ligament which unites the two bones is lodged. To the front and inner side of this groove, there is an elongated articular facet directed obliquely from behind forwards and outwards, and concave in the direction of its long axis. This is frequently divided into two smaller oval areas by an intermediate non-articular surface. Of these facets the hinder (facies articularis media) articulates with the middle calcanean facet on the under surface of the astragalus, whilst the anterior (facies articularis anterior) supports the under surface of the head of the astragalus (facies articularis calcanei anterior). The outer side of the upper surface of the anterior extremity of the bone is rough, and hereto is attached the origin of the short extensor muscle of the toes.

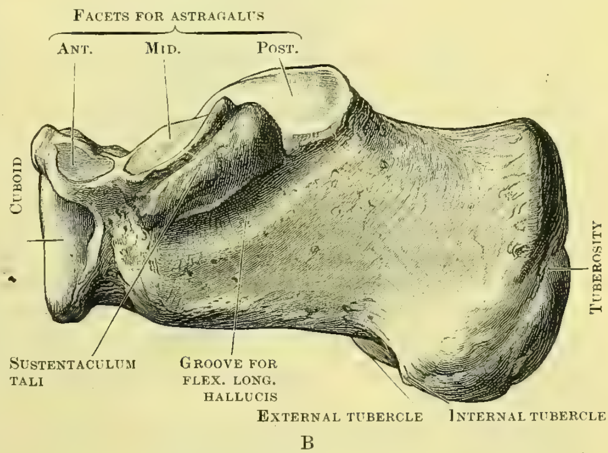
The *inferior surface* of the bone is slightly concave from before backwards, and convex from side to side. The under aspect of the tuberosity is provided with two **tubercles**, an **inner** (processus medialis tuberis calcanei) and an **outer** (processus lateralis tuberis calcanei), of which the former is the larger. From this the short flexor of the toes and the abductor hallucis muscle arise, whilst from both tubercles

spring the fibres of origin of the abductor minimi digiti muscle. On the fore-part of the under surface there is an elevated elongated tubercle, which terminates somewhat abruptly just behind the anterior border of this aspect of the bone, giving rise at times to a notch. From the former spring the fibres of the long plantar ligament, whilst the latter serves for the attachment of the deeper fibres of the short plantar ligament. The two heads of origin of the flexor accessorius muscle arise from the bone on either side of the long plantar ligament. The *internal surface* of the os calcis is crossed obliquely from above downwards and forwards by a broad groove of considerable depth; along this pass many of the structures which enter the sole of the foot from the back of the leg. The groove is overhung in front and above by a projecting bracket-like process, called the **sustentaculum tali,** or **lesser process.** The under surface of the sustentaculum is channelled by a groove, in which is lodged the tendon of the flexor longus hallucis muscle; whilst its inner border, to which is attached a part of the internal lateral ligament of the ankle, is overlain by the tendon of the flexor longus digitorum. To the anterior border of the sustentaculum is attached the inferior calcaneo-navicular ligament, and placed on its upper surface is the articular facet already alluded to (facies articularis media). Posteriorly the internal surface of the bone is limited inferiorly by the projection of the internal tubercle, and above by the internal lipped edge of the tuberosity.

The *external surface,* broad behind and narrower in front, is of flattened form. Springing from it, just below the outer end of the sinus tarsi, is the **peroneal spine** (processus trochlearis), often indistinctly marked. To this the fibres of the external annular ligament are attached; whilst in grooves above and below it pass the tendons of the peroneus brevis and longus muscles respectively. To the upper and back part of this surface are attached the fibres of the middle fasciculus of the external lateral ligament of the ankle.



A, As seen from the Outer Side.



B, As seen from the Inner Side.

FIG. 179.—THE RIGHT OS CALCIS.

The *anterior extremity,* sometimes called the **greater process,** is furnished with a saddle-shaped surface on its anterior aspect for articulation with the cuboid. This facet is concave from above downwards, and slightly convex from side to side; its edges are sharply defined, except internally, and serve for the attachment of ligaments.

The *posterior extremity,* called the **tuberosity** (tuber calcanei) forms the projection of the heel. Of oval form and rounded surface, it rests upon the two tubercles inferiorly. Its cutaneous aspect is divisible into three areas. Of these the highest is smooth and crescentic, and is covered by a bursa; the intermediate is

also fairly smooth, and is defined inferiorly by an irregular line, sometimes a definite ridge, the edges of which are striated. Into this surface the tendo Achillis is inserted. The lowest surface is rough and striated, and is confluent below with the internal and external tubercles; this is overlain by the dense layer of tissue which forms the pad of the heel.

Variations.—The peroneal tubercle is occasionally unduly prominent, constituting the submalleolar apophysis of Hyrtl, and cases are recorded of the os calcis articulating with the navicular (Morestin, H., *Bull. de la Soc. Anat. de Paris*, 1894, ser. v., t. 8, n. 24, p. 798; and Petrini, *Atti del XI. Congr. Med. Internaz. Roma*, 1894, vol. ii, "Anat." p. 71). Phitzner (*Morphologische Arbeiten*, vol. vi. p. 245) also records the separation of the sustentaculum tali to form an os sustentaculi.

THE NAVICULAR BONE.

The **navicular** or **scaphoid bone** (os naviculare pedis), of compressed pyriform shape, is placed on the inner side of the foot, between the head of the astragalus posteriorly and the three cuneiform bones anteriorly. The bone derives its name from the oval or boat-shaped hollow on its *posterior surface*, which rests upon the head of the astragalus. Its *anterior aspect* is furnished with a semilunar articular area, which is subdivided by two faint ridges into three wedge-shaped facets for articulation from within outwards with the internal, middle, and external cuneiform bones. *Superiorly* the surface of the bone, convex from side to side, is rough for the attachment of the ligaments on the dorsal aspect of the foot. *Inferiorly* the bone is irregularly concave, and marked by the attachment of the plantar ligaments. The *external surface* is narrow from before backwards, and rounded from above downwards. Usually devoid of any articular surface, it is occasionally provided with a facet, which rests upon a corresponding area on the cuboid. The *inner side* of the bone projects beyond the general line of the inner border of the foot, so as to form a thick rounded **tubercle** (tuberositas oss. navicularis), the position of which can be easily determined in the living. To the inner and under surface of this process an extensive portion of the tendon of the tibialis posticus muscle is inserted.

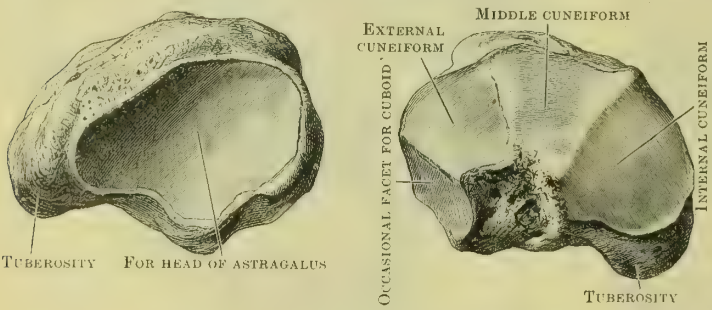


Fig. 180.—The Right Navicular Bone.
A, As seen from Behind; B, As seen from the Front.

Variations.—Cases are recorded where the tubercle has formed an independent ossicle.

THE CUNEIFORM BONES.

The **cuneiform bones**, three in number, are placed between the navicular posteriorly and the bases of the first, second, and third metatarsal bones anteriorly, for which reason they are frequently named the first, second, and third cuneiforms, or, from their position, internal, middle, and external. More or less wedge-shaped, as their name implies, the internal or first is the largest, whilst the middle or second is the smallest of the group. Combined, they form a compact mass, the proximal surface of which, fairly regular in outline, rests on the anterior surface of the navicular; whilst anteriorly they form a base of support for the three inner metatarsals, the outline of which is irregular, owing to the base of the second metatarsal bone being recessed between the inner and outer cuneiforms as it articulates with the distal extremity of the shorter middle cuneiform.

The **internal cuneiform bone** (os cuneiforme primum), the largest of the three, lies on the inner border of the foot between the base of the metatarsal bone of the

great toe in front, and the fore and inner part of the navicular behind. Its *upper*, *lower*, and *internal* surfaces are confluent, and form a convexity from above downwards, which is most pronounced inferiorly, where it is turned towards the plantar side of the foot. On the fore part of the inner aspect of the bone there is usually a distinct oval impression, which indicates the surface of insertion of a portion of the tendon of the tibialis anticus muscle. Elsewhere this surface is rough for ligamentous attachments. The *external surface* of the bone, quadrilateral in shape, is directed towards the middle cuneiform; but as it exceeds it in length, it also comes in contact with the inner side of the base of the second metatarsal bone. Running along the posterior and upper edges of this area is an ⌐-shaped articular surface, the fore and upper part of which is for the base of the second metatarsal bone, the remainder articulating with the inner side of the middle cuneiform. The non-articular part of this aspect of the bone is rough for the attachment of the strong interosseous ligaments, which bind it to the middle cuneiform and second metatarsal bones respectively. The *posterior* or *proximal end* of the bone is provided with a pyriform facet which fits on the inner articular area of the navicular. *Anteriorly* the vertical diameter of the bone is much increased, and the facet for the base of the metatarsal bone of the great toe is consequently much larger than that for the navicular. The metatarsal facet is usually of semilunar form, but not infrequently is more reniform in shape, and may in some cases display complete separation into two oval portions.

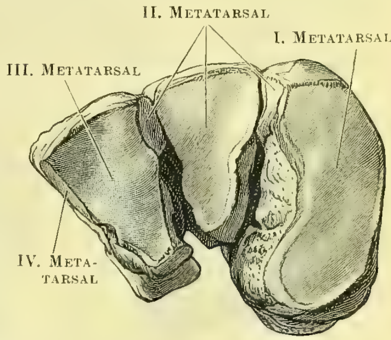


Fig. 181.—Anterior View of the three Cuneiform Bones of the Right Foot.

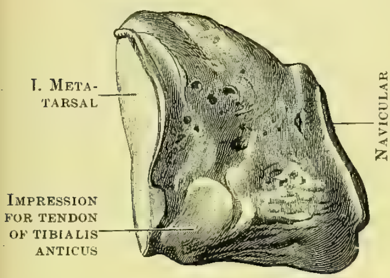


Fig. 182.—The Right Internal Cuneiform (Inner Side).

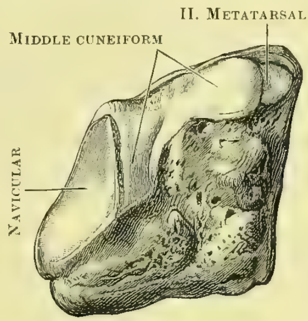


Fig. 183.—The Right Internal Cuneiform (Outer Side).

The **middle** or **second cuneiform** (os cuneiforme secundum) is of a typical wedge shape; shorter than the others, it lies between them, articulating with the base of the second metatarsal in front, and the middle facet on the anterior surface of the navicular behind. Its *upper aspect*, which corresponds to the base of the wedge, conforms to the roundness of the instep, and is slightly convex from side to side, affording attachments for the dorsal ligaments. Its under surface is narrow and tubercular, forming the edge of the wedge; with this the plantar ligaments are connected. The *inner surface*, quadrilateral in outline, is furnished with an ⌐-shaped articular area along its posterior and superior borders in correspondence with the similar area on the outer side of the internal cuneiform. The rest of this aspect is rough for ligaments. The *outer side* displays a facet arranged along its posterior border, and usually somewhat constricted in the middle; this is for the external cuneiform. In front of this the bone is rough for the interosseous ligaments, which bind the two bones together. The proximal end is provided with a triangular facet slightly concave from above

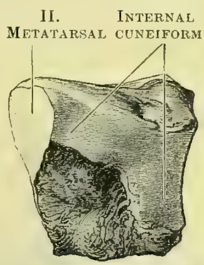


Fig. 184.—The Right Middle Cuneiform (Inner Side).

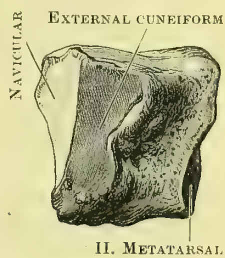


Fig. 185.—The Right Middle Cuneiform (Outer Side).

downwards; this rests on the central articular surface on the anterior aspect of the navicular. In front the bone articulates by means of a wedge-shaped facet with the base of the metatarsal bone of the second toe.

The **external** or **third cuneiform** (os cuneiforme tertium) intermediate in size between the first and second, is also of a typical wedge shape. Its *superior surface*, slightly convex from side to side, provides attachments for the dorsal ligaments. Its *inferior* or *plantar aspect* is narrow and tubercular, and serves for the attachment of the plantar ligaments. Its *inner side*, of quadrilateral form, displays two narrow articular strips, placed along its anterior and posterior borders respectively, each somewhat constricted in the middle. The anterior articulates with the outer side of the base of the second metatarsal bone, the posterior with the outer side of the middle cuneiform. The rough non-articular surface, which separates the two elongated facets, serves for the attachment of ligaments. The *outer aspect* of the bone is characterised by a large circular or oval facet, placed near its hinder border, for articulation with the cuboid; in front of this the anterior border is lipped above by a small semi-oval facet for articulation with the inner side of the base of the fourth metatarsal. The rest of the bone around and between these facets is rough for ligaments. *Proximally* the bone is furnished with a triangular facet for articulation with the outer wedge-shaped area on the front of the navicular, whilst *distally* it articulates with the base of the third metatarsal by a surface of corresponding shape.

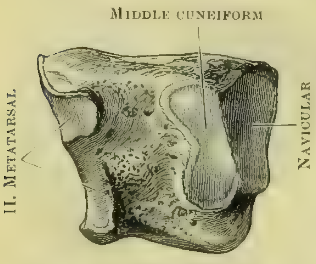


Fig. 186.—Right External Cuneiform (Inner Side).

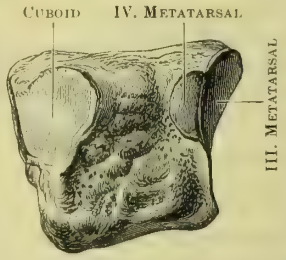


Fig. 187.—Right External Cuneiform (Outer Side).

Variations.—Numerous cases of division of the internal cuneiform bone into dorsal and plantar parts have been recorded; the frequent division of its metatarsal articular facet is no doubt correlated with this anomalous condition.

The Cuboid Bone.

The **cuboid** (os cuboideum) lies on the outer side of the foot, about its middle, articulating with the os calcis behind and the fourth and fifth metatarsal bones in front. Its *upper surface*, plane in an antero-posterior direction, is slightly rounded from side to side, and provides attachment for ligaments. Its *plantar aspect* is traversed obliquely from without inwards and forwards by a thick and prominent ridge, the outer extremity of which, at the point where it is confluent with the outer surface, forms a prominent **tubercle** (tuberositas oss. cuboidei), the anterior and external surface of which is smooth and faceted to allow of the play of a sesamoid bone which is frequently developed in the tendon of the peroneus longus muscle. In front of this ridge there is a groove (sulcus peronæi) in which the tendon of the peroneus longus muscle is lodged as it passes across the under surface of the bone. Behind the ridge the bone is rough, and serves for the attachment of the short plantar ligament, the superficial fibres of which pass

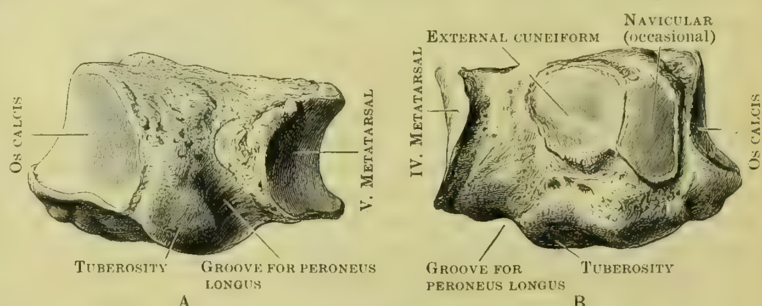


Fig. 188.—The Right Cuboid Bone.

A, Outer Side. B, Inner Side.

forwards and are attached to the summit of the ridge. The *outer aspect* of the bone is short and rounded, and is formed by the confluence of the superior and inferior surfaces; it is more or less notched by the peroneal groove which turns round its lower edge. The *internal surface* of the bone is the most extensive; it is easily recognisable on account of the presence of a rounded or oval facet situated near its middle and close to its upper border. This is for articulation with the outer side of the external cuneiform; in front and behind this the surface is rough for ligaments. Not infrequently behind the facet for the external cuneiform there is a small articular surface for the navicular, as is the case normally in the gorilla, whilst behind and below, the projecting inferior angle is sometimes provided with a facet, on which the head of the astragalus rests (Sutton, "Proc. Anat. Soc.," *Journ. Anat. and Physiol.*, vol. xxvi. p. 18). The *anterior surface* is oval or conical in outline; sloping obliquely from within outwards and backwards, it is divided about its middle by a slight vertical ridge into two parts, the inner of which articulates with the base of the fourth metatarsal bone, the outer with that of the fifth. The *posterior surface*, also articular, has a semilunar outline, the convex margin of which corresponds to the dorsal roundness of the bone. The inferior external angle corresponds to the tubercle on the outer border of the bone, whilst the inferior internal angle forms a pointed projection, which is sometimes called the calcanean process. The posterior surface articulates with the os calcis by means of a saddle-shaped facet, which is convex from side to side, and concave from above downwards.

Variations.—Blandin has recorded a case of division of the cuboid.

The **tarsus as a whole** may be conveniently described as arranged in two columns; the inner, corresponding to the inner border of the foot, comprising the astragalus, navicular, and three cuneiforms, and forming a base for the support of the three inner metatarsal bones and their phalanges. The outer column, formed by the os calcis and cuboid, supports the fourth and fifth metatarsal bones together with their phalanges. The superior surface of the anterior portion of the tarsus determines the side-to-side roundness of the instep, whilst its under surface forms arches in both a transverse and longitudinal direction, in which the softer tissues of the sole are lodged, and so protected from injury.

Architecture of the Bones of the Foot.—A longitudinal section through the articulated bones of the foot reveals the fact that the cancellous structure of each individual bone is determined by the stress to which it is habitually subjected. In this connection it is necessary to refer to the arched arrangement of the bones of the foot, a subject which is elsewhere treated in detail (see p. 304). The summit of the arch is formed by the astragalus, on which rests the tibia. Subjected as the astragalus is to a crushing strain, it is obvious that this load must be distributed throughout the arch, of which the os calcis is the posterior pillar, whilst the heads of the metatarsal bones constitute the anterior pillar. It is found, consequently, that the lamellæ of the cancellous tissue of the astragalus are arranged in two directions, which intercross and terminate below the superior articular surface. Of these fibres, some sweep backwards and downwards towards the posterior calcanean facet, beyond which they are carried in the substance of the os calcis in a curved and wavy manner in the direction of the heel, where they terminate; whilst others, curving downwards and forwards from the trochlea of the astragalus, pass through the neck to reach the articular surface of the head, through which in like manner they may be regarded as passing onwards through the several bones which constitute the anterior part of the arch, thus accounting for the longitudinal striation as displayed in the structure of the navicular, cuneiform and metatarsal bones. In the os calcis, in addition to the foregoing arrangement, another set of curving fibres sweep from back to front of the bone beneath the more compact tissue which forms its under shell. These are obviously of advantage to prevent the spread of the bone when subjected to the crushing strain. In the sustentaculum tali a bracket-like arrangement of fibres is evident, and the under surface of the neck of the astragalus is further strengthened by lamellæ arranged vertically.

In the separate bones the investing envelope is thin, though under the articular surfaces there is a greater density, due to the accession of lamellæ lying parallel to the articular planes. The stoutest bony tissue in the astragalus is met with in the region of the under surface of the neck, whilst in the os calcis the greatest density occurs along the floor of the sinus tarsi.

Numerical Variation in the Tarsus.—**Increase in the number** of the tarsal elements may be due to the occurrence of division of either the internal cuneiform or the cuboid bone, or to the occasional presence of an os trigonum. Cases of separation of the tuberosity of the navicular bone have been recorded, and instances of supernumerary ossicles between the internal cuneiform and second metatarsal bone have been noted. Stieda mentions the occurrence of a small ossicle in connexion with the articular surface on the fore and upper part of the os calcis, and Phitzner notes the occurrence of an os sustentaculi. For further information on the variations of the skeleton of the foot, see Phitzner (*Morphologische Arbeiten*, vol. vi. p. 245).

The **reduction in the number** of the tarsus is due to the osseous union of adjacent bones. In many cases this is undoubtedly pathological, but cases have been noticed (Leboucq) of fusion of

the cartilaginous elements of the os calcis and astragalus, and the os calcis and navicular in fœtuses of the third month.

Ossification.—Unlike the carpus, the tarsus is at birth partially ossified. At this period there is a well-marked osseous nucleus within the body and neck of the astragalus, and the os calcis is extensively ossified. In the latter the deposition of earthy matter appears as early as the sixth month of fœtal life, whilst in the astragalus the ossific centre makes its appearance in the later weeks of gestation. Shortly before or after birth the cuboid begins to ossify, succeeded early in the first year by the external cuneiform, followed in order by the middle cuneiform, internal cuneiform, and navicular. The ossific centre of the latter appears at the third year or somewhat later. An epiphysis, which forms a cap over the extremity of the great tuberosity of the os calcis, appears from the seventh to to the ninth year, and fusion is completed between the ages of sixteen and twenty.

The Metatarsus.

The **metatarsal bones**, five in number, in their general configuration resemble the metacarpus. They are, however, slightly longer, their bases are proportionately larger, their shafts more slender and laterally compressed, and their heads proportionately smaller. They are named numerically the first, second, third, fourth, and fifth metatarsal bones, in order from within outwards. The first can be readily recognised on account of its stoutness; it is also the shortest of the series. The second is the longest of the five, and the fifth can easily be distinguished by the projecting tubercle at its base.

The **first metatarsal** or metatarsal bone of the great toe, the shortest of the series, is remarkable for its stoutness. The vertical diameter of its base much exceeds its transverse width, here the bone is provided with a reniform facet for articulation with the internal cuneiform. As a rule there are no facets on the lateral aspects of the base. The inferior angle projects backwards and outwards, and forms a prominent tubercle which is pitted for the insertion of the tendon of the peroneus longus muscle, whilst its internal margin is lipped by a surface for the attachment of part of the tendon of the tibialis anticus. The shaft, short, thick, and prismatic on section, tapers rapidly towards the head, the fore and under surfaces of which are articular. The former is convex from side to side, and from above downwards, and supports the proximal phalanx. It is confluent below with the inferior articular surface, which is divided by a median ridge into two shallow grooves of which the inner is the wider. In these grooves are lodged the two sesamoid bones which underlie the metatarso-phalangeal joint. On either side of the head, the bone is pitted for the strong lateral ligaments of the joint.

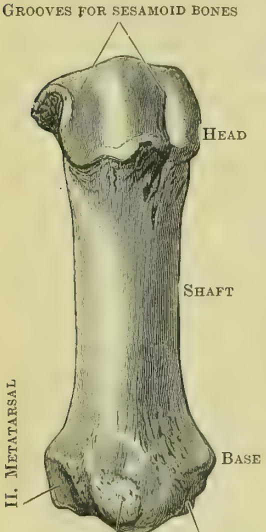


Fig. 189.—The First Metatarsal Bone of the Right Foot (plantar aspect).

The **second metatarsal**, the longest of the series, has a base of wedge-shaped form, the proximal aspect of which articulates with the middle cuneiform. On its inner aspect, near its superior edge, there is a small circular facet for the internal cuneiform; below and in front of this there is sometimes a tubercle with a "pressure" facet on it, where the bone comes in contact with the base of the first metatarsal. On the outer side of the base there is one, more usually two facets, each divided into two parts, a posterior for articulation with the external cuneiform, and an anterior for the base of the third metatarsal. The shafts of this and the three succeeding bones are slender and laterally compressed. The heads are small and narrow, and display a pronounced side-to-side and vertical convexity.

The **third metatarsal bone** also possesses a base of wedge-shaped form, the proximal surface of which articulates with the external cuneiform. On its inner side it is provided with one, more usually two small facets, for articulation with the base of the second metatarsal. Externally the base has a larger facet for articula-

tion with the base of the fourth metatarsal, more or less conical in outline, and having its lower edge sharply defined by a narrow groove which underlies it.

The **fourth metatarsal** has a base more cubical in shape. Its proximal aspect articulates with the cuboid, whilst internally an elongated oval facet, divided by a

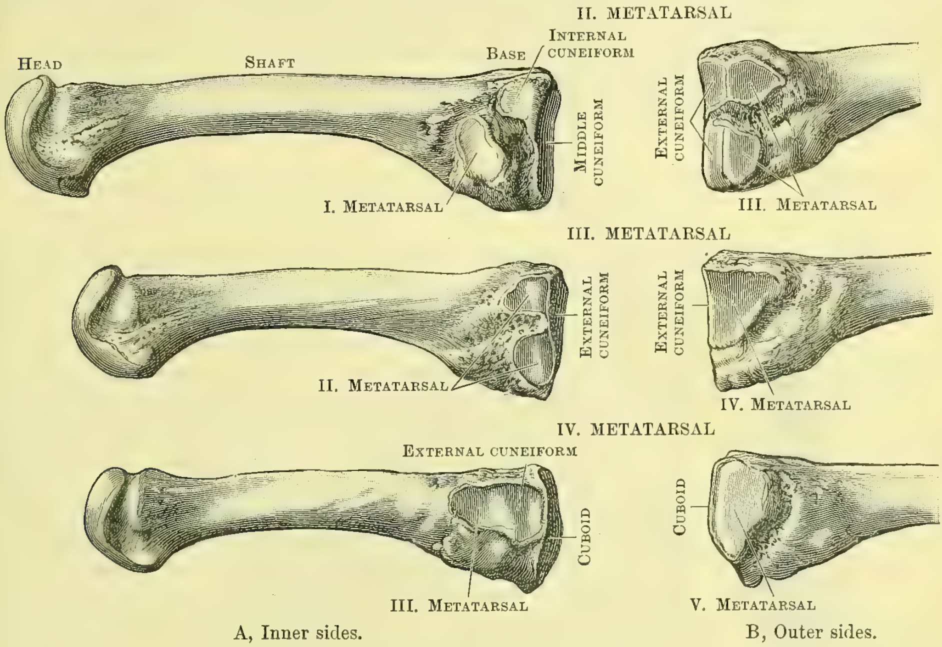


FIG. 190.—VIEW OF THE BASES AND SHAFTS OF THE SECOND, THIRD, AND FOURTH METATARSAL BONES OF THE RIGHT FOOT.

slight vertical ridge, provides surfaces for articulation with the third metatarsal in front and the outer side of the internal cuneiform behind. On the outer side there is a demi-oval facet, bearing a slightly saddle-shaped surface, for articulation with the inner side of the base of the fifth metatarsal.

The **fifth metatarsal** can be readily recognised by the peculiar shape of its base, from the outer side of which there projects backwards and outwards a prominent tubercle (tuberositas oss. metacarpi V.). To the hinder extremity of this is attached the tendon of the peroneus brevis muscle. To its upper surface the tendon of the peroneus tertius is inserted, whilst its under surface provides an origin for the flexor brevis minimi digiti muscle. The inner surface of the base is provided with a demi-oval, slightly concave facet, for the outer side of the base of the fourth metatarsal, whilst proximally it articulates with the cuboid by means of a semi-circular facet.

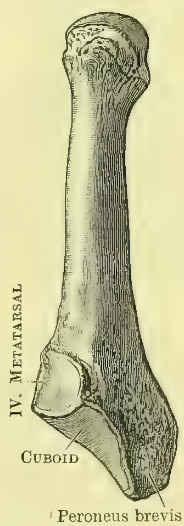


FIG. 191.—FIFTH RIGHT METATARSAL BONE (dorsal aspect).

Vascular Foramina.—The canals for the nutrient vessels open, as a rule, on the plantar aspects of the middle of the shafts. Those of the outer metatarsals are directed towards the bases of the bones, whilst that for the metatarsal of the great toe passes towards its head.

Architecture.—In structure and the arrangement of their lamellæ the metatarsal bones agree with the metacarpus.

Variations.—Several instances of separation of the tuberosity of the fifth metatarsal (os Vesaleanum) have been recorded, whilst numerous examples of an os intermetatarsum between the bases of the first and second metatarsal bones have been recorded by Gruber and others. The tubercle on the base of the first metatarsal for the attachment of the peroneus longus tendon is occasionally met with as a separate ossicle.

Ossification.—In correspondence with the mode of ossification which maintains in the metacarpus, the primary centres for the metatarsus appear as early as the third month of fœtal life. In the case of the second, third, fourth, and fifth, these centres furnish the bases and shafts of the bones, the heads

being developed from secondary centres which appear from two to four years after birth, fusion with the shaft being usually completed about the eighteenth year. In striking contrast to this is the mode of ossification of the first metatarsal. From its primary centre the head and shaft is developed; the secondary centre appears at its **base** about the second or third year, and fuses with the shaft about eighteen. In this respect, therefore, the metatarsal bone of the great toe resembles in its mode of development the phalanges. Mayet, however (*Bull. Soc. Anat. Paris*, 1895), describes the occurrence of two ossific centres in the proximal epiphysis. These fuse early, and he considers that the one represents the metatarsal element, whilst the other may be regarded as phalangeal in its origin.

The Phalanges.

The **phalanges** of the toes (phalanges digitorum pedis) differ from those of the fingers in the striking reduction of their size, and in the case of the bones of the first row, in the lateral compression of their shafts. Each toe is provided normally with three phalanges, except the great toe, which has only two. In their general configuration and in the arrangement of their articular facets, they resemble the digital phalanges, though, owing to the reduction in their size, the shafts, particularly those of the second row, are often so compressed longitudinally as to reduce the bone to a mere nodule. The proximal end of each of the bones of the first row is proportionately large, and is provided with a simple hollow in which the head of the metatarsal bone rests; the distal ends are furnished with condyloid surfaces. The proximal extremities of the second row are each provided with two small concavities, separated by a slight ridge for articulation with the condyles of the first row. The joint between the second and third row displays the same arrangement — the third, terminal or ungual phalanx, being easily distinguished by the spatula-shaped surface at its extremity on which the bed of the nail is supported.

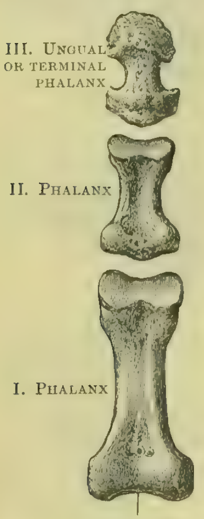


Fig. 192.—The Phalanges of the Toes (dorsal aspect).

The phalanges of the great toe, two in number, differ from the others in their size and length. Into the base of the first phalanx are inserted the short muscles of the great toe, whilst the second phalanx receives on its plantar aspect the insertion of the flexor longus hallucis muscle, the tendon of the extensor longus hallucis being inserted into the dorsal aspect.

Architecture.—In their general structure they resemble the bones of the fingers.

Variations.—It is not uncommon to meet with fusion of the second and third phalanges, particularly in the fifth, less frequently in the fourth, and occasionally in the second and third toes. The union of the phalangeal elements has been observed in the fœtus as well as the adult (Phitzner). The proportionate length of the phalanges varies much; in some cases the ungual phalanges are of fair size, the bones of the second row being mere nodules, whilst in other instances the reduction in size of the terminal phalanges is most marked.

Ossification.—Each phalanx is developed from two centres—one primary for the shaft and distal extremity, the other for the epiphysis on the proximal end. The primary centres for the ungual phalanges are the first to appear, commencing to ossify from the eleventh to the twelfth week of fœtal life. The centre for the ungual phalanx of the great toe makes its appearance before that of its corresponding metatarsal bone. The primary centres for the phalanges of the first row appear from the fourteenth to the sixteenth week. The primary centres for the middle phalanges of the second and third toes begin to ossify about the sixth month, those for the fourth and fifth toes not till later—the shaft of the middle phalanx of the fourth toe being frequently cartilaginous at birth, the normal condition in the case of the fifth toe (Lambertz). The proximal epiphyses do not begin to ossify until about the fourth year, and are usually fused with the diaphyses about the age of sixteen or eighteen. Union between the shafts and epiphyses of the first row precedes that of the second and third rows.

Sesamoid Bones.

As in the hand, small independent nodules of bone, called **sesamoid bones**, are met with in the ligaments and tendons of the foot. The most constant of these are found in connexion with the metatarso-phalangeal articulation of the great toe, where they lie in grooves on the under surface of the head of the metatarsal bone in connexion with the tendons of the short muscles of the great toe. Small osseous nodules occupying a corresponding position are occasionally met with in the other toes, and instances have been recorded of like ossicles occurring on the plantar aspect of the interphalangeal joint of the great toe.

An osseous nodule is not infrequently met with in the tendon of the peroneus longus as it turns round the outer border of the foot to lie in the groove on the under surface of the cuboid.

MORPHOLOGY OF LIMBS.

Morphology of the Appendicular Skeleton.

The paired limbs first appear in the human embryo about the third week as small buds on either side of the cephalic and caudal ends of the trunk. That these outgrowths are derived from a large number of trunk segments is assumed on the ground that they are supplied by a corresponding number of segmental nerves, and the circumstance that they are more particularly associated with the ventral offsets of these nerves would point to the conclusion that they belong rather to the ventral than the dorsal surface of the body.

At first the surfaces of these limb buds are so disposed as to be directed ventrally and dorsally, the ventral aspect corresponding to the future flexor surface of the limb, the dorsal to the extensor side. At the same time, the borders are directed headwards (pre-axial), and tailwards (post-axial). As the limbs grow, they soon display evidence of division into segments corresponding to the hand and foot, forearm and leg, upper arm and thigh. Coincident with this (about the second month) the cartilaginous framework of the limb is being differentiated. The disposition of these cartilages furnishes a clue to their homologies. In the fore limb, the radius and thumb lie along the pre-axial borders, and correspond to the tibia and great toe, which are similarly disposed in the hind limb; whilst the ulna and fifth finger are homologous with the fibula and fifth toe, which are in like manner arranged in relation to the posterior (post-axial) border of their respective limbs. Up to this time the limbs are directed obliquely ventralwards from the head towards the tail-end of the embryo. During the third month, however, a change in their position takes place, owing to their axes being rotated in opposite directions. The fore limb is turned outwards and forwards to the extent of 90°, whilst the lower hind limb is twisted inwards and backwards to a corresponding degree. This gives rise to a change in the disposition of the joints of the flexor and extensor surfaces. The flexor surface of the elbow is now directed forwards, whilst the corresponding aspect of the knee is turned backwards, and in consequence the dorsal or extensor aspect of the fore limb is posterior, whilst the dorsal or extensor aspect of the hind limb has become anterior. Correspondingly, the pre-axial border of the fore limb with the thumb now lies external, whilst the pre-axial border of the hind limb with the great toe has become internal. A knowledge of these changes is necessary to account for the homologies of the various structures within the limb. In the axial mesoderm of each member, differentiation into cartilaginous segments begins about the second month; each of these cartilages becomes invested by a perichondrial layer which stretches from segment to segment, and ultimately forms the ligaments surrounding the joints, which are subsequently developed between the segments. Chondrification first begins in the basal part of the limb, and extends towards the digits. In the upper arm and thigh the humerus and femur are homodynamous. In the forearm and leg the pre-axial radius corresponds with the pre-axial tibia, and the post-axial ulna with the post-axial fibula. The homodynamy of the carpal and tarsal elements may be tabularly expressed, and compared with the more generalised types from which they are evolved.

Type.	Hand.	Foot.
Radiale (Tibiale)	= Scaphoid (body)	= Astragalus.
Intermedium	= Semilunar	= Absent, or Os trigonum (?)
Ulnare (Fibulare)	= Cuneiform	= Os Calcis.
Centrale	= Absent, or Tubercle on Scaphoid	= Navicular.
Carpale (Tarsale), i.	= Trapezium	= Internal Cuneiform.
Carpale (Tarsale), ii.	= Trapezoid	= Middle Cuneiform.
Carpale (Tarsale), iii.	= Os Magnum	= External Cuneiform.
Carpale (Tarsale), iv. } Carpale (Tarsale), v. }	= Unciform	= Cuboid.

The pisiform is omitted from the above table, since it is now generally regarded as being a vestige of an additional digit placed post-axial to the little finger (digitus post-minimus). Its homologue in the foot is by some considered as fused with the os calcis. Similarly, on the pre-axial border of the hand and foot, vestiges of a suppressed digit (prepollex and prehallux) may

occasionally be met with. The frequent occurrence of an increase in the number of digits seems to indicate that phylogenetically the number of digits was greater than at present, and included a prepollex or prehallux, and a digitus post-minimus. The correspondence of the metacarpus with the metatarsus and the phalanges of the fingers with those of the toes is so obvious, that it is sufficient merely to mention it.

The differences in size, form, and disposition of the skeletal elements of the hand and foot is easily accounted for by a reference to the functions they subserve.

In the hand strength is sacrificed to mobility, thus leading to a reduction in the size of the carpal elements, and a marked increase in the length of the digital phalanges. The freedom of movement of the thumb, and its opposability to the other digits, greatly enhances the value of the hand as a grasping organ. In the foot, where stability is the main requirement, the tarsus is of much greater proportionate size, whilst the phalanges are correspondingly reduced. Since the foot no longer serves as a grasping organ, the great toe is not free and opposable like the thumb.

Limb Girdles.—The free limbs are linked to the axial skeleton by a chain of bones which constitute their girdles. The fundamental form of these limb girdles consists each of a pair of curved cartilages placed at right angles to the axis of the trunk, and embedded within its musculature. Each cartilage has an articular surface externally about the middle for the reception of the cartilage of the first segment of the free limb. In this way each pectoral and pelvic cartilage is divided into an upper or dorsal half and a lower or ventral half. The dorsal halves constitute the scapula and ilium of the pectoral and pelvic girdles respectively. With regard to the ventral halves, there is more difficulty in establishing their homologies. The original condition is best displayed in the pelvic girdle; here the ventral segment divides into two branches—one anterior, which represents the pubis, the other posterior, which ultimately forms the ischium. Ventrally, the extremities of these cartilages unite to enclose the obturator foramen. In the pectoral girdle the disposition of the ventral cartilages is not so clear, consisting primitively of an anterior branch or precoracoid, and a posterior portion or coracoid; these, in higher forms, have undergone great modifications in adaptation to the requirements of the fore limbs. The posterior or coracoid element, the homologue of the ischial cartilage in the pelvic girdle, is but feebly represented in man by the coracoid process and the coraco-clavicular ligament. With regard to the homologue of the pubic element in the pectoral girdle, there is much difference of opinion; in reptiles and amphibia it corresponds most closely to the precoracoid, but it is doubtful what represents it in mammals. According to Goette and Hoffman, the clavicle is a primordial bone, and not, as suggested by Gegenbaur, of secondary or dermic origin. If this be so, it corresponds to the ventral anterior segment of the pectoral girdle, and is therefore homologous with the ventral anterior (pubic) segment of the pelvic girdle. On the other hand, if Gegenbaur's view be accepted, the clavicle has no representative in the pelvic girdle. It must, however, be borne in mind that during its ossification it is intimately associated with cartilage, and that that cartilage may represent the precoracoid bar; nor must too great stress be laid upon the fact that the clavicle begins to ossify before it is preformed in cartilage, since that may be merely a modification in its histogenetic development.

According to another view (Sabatier), the subcoracoid centre (see Ossification of Scapula) is derived from the posterior ventral segment, and corresponds to the ischium, whilst the coracoid process is the remains of the anterior ventral segment (precoracoid), and is homodynamous with the pubis.

In no part of the skeleton does function react so much on structure as in the arrangement of the constituent parts of the pectoral or pelvic girdles. In man, owing to the assumption of the erect position and the bipedal mode of progression, the pelvic girdle acquires those characteristics which are essentially human, viz. its great relative breadth and the expansion of its iliac portions, which serve as a support to the abdominal viscera, and also furnish an extensive origin to the powerful muscles which control the movements of the hip-joint. The stability of the pelvic girdle is ensured by the nature of its union with the axial skeleton, as well as by the osseous fusion of its several parts, and their union in front at the symphysis pubis.

In man, since the erection of the figure no longer necessitates the use of the fore limb as a means of support, the shoulder girdle has become modified along lines which enhance its mobility and determine its utility, in association with a prehensile limb. Some of its parts remain independent (clavicle and scapula), and are united by diarthrodial joints, whilst others have become much reduced in size or suppressed (coracoid-precoracoid, see *ante*). The dorsal part of the girdle (scapula) is not directly united with the axial skeleton as is the ilium, but is only indirectly joined to it through the medium of the clavicle, which is linked in front with the presternum. The same underlying principles determine the differences in mobility and strength between the shoulder, elbow, and wrist, and the hip, knee, and ankle joints of the fore and hind limbs respectively, whilst the utility of the hand is further enhanced by the movements of pronation and supination which occur between the bones of the forearm. In the leg such movements are absent, as they would interfere with the stability of the limb.

THE ARTICULATIONS OR JOINTS.

ARTHROLOGY.

By David Hepburn.

Arthrology is that branch of human anatomy which treats of the articulations or joints.

An articulation or joint constitutes a mode of union or connexion subsisting between any two separate segments or parts of the skeleton, whether osseous or cartilaginous, and having for its primary object either the preservation of a more or less rigid continuity of the parts joined together or else to permit of a variable degree of mobility, subject to the restraints of the uniting media.

Classification of Joints.—In attempting to frame a classification of the numerous joints in the body, several considerations must be taken into account, viz. the manner and sequence of their appearance in the embryo; the nature of the uniting media in the adult, and also the degree and kind of movement permitted in those joints where movement is possible.

In this way we obtain two main subdivisions of joints:—

(1) Those in which the uniting medium is coextensive with the opposed surfaces of the bones entering into the articulation, and in which a direct union of these surfaces is thereby effected.

(2) Those in which the uniting medium has undergone more or less of interruption in its structural continuity, and in which a cavity of greater or less extent is thus formed in the interior of the joint.

To the first group belong all the immovable joints, many of which are likewise of temporary duration; to the second group belong all joints which possess as their outstanding features mobility and permanence.

SYNARTHROSES.

The general characteristics of this group are partly positive and partly negative. Thus there is uninterrupted union between the opposed surfaces of the bones joined together at the plane of the articulation, *i.e.* there is no trace of a joint cavity, and further, there is an entire absence of movement. Developmentally, these joints result from the approximation of ossific processes which have commenced from separate centres of ossification, and therefore the nature of the uniting medium varies according as the bones thus joined together have originally ossified in membrane or in cartilage. In the former case, union is effected by an interposed fibrous membrane continuous with and corresponding to the periosteum. To such articulations the term **suture** (Fig. 193) is applied. In the latter case, the uniting medium is a plate of hyaline cartilage. Such

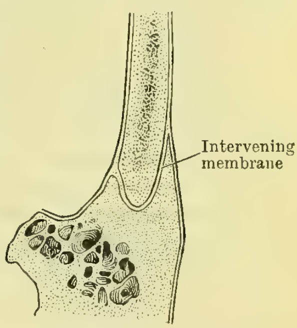


Fig. 193.—Vertical Section through a Suture.

articulations are called **synchondroses** (Fig. 194). In all the synchondroses, and in many of the sutures, the uniting medium tends to disappear in the progress of

ossification, and thus the plane of articulation becomes obliterated, so that direct structural continuity between the osseous segments takes place. The primary features common to all synarthroses are—(*a*) continuous and direct union of the opposing surfaces; (*b*) no joint cavity; (*c*) no movement.

Fig. 194. — Section through the Occipito-sphenoid Synchondrosis.

Suture.—This form of synarthrosis is only found in connexion with the bones of the skull. In a large number of cases the bones which articulate by suture present irregular interlocking margins between which there is the interposed fibrous membrane to which reference has already been made. When these interlocking margins present well-defined projections they are said to form true sutures—**sutura vera**; on the other hand, when the opposed surfaces present ill-defined projections, or even flat areas, they are described as false sutures—**sutura notha**. In each of these subdivisions the particular characters of the articulating margins are utilised in framing additional descriptive terms. Thus true sutures may possess interlocking margins whose projections are tooth-like (sutura dentata), *e.g.* in the interparietal suture; saw-like (sutura serrata), (Fig. 195) *e.g.* in the interfrontal suture; ridge-like, or comparable to the parallel ridges on the welt of a boot (sutura limbosa). Similarly false sutures may articulate by margins which are scale-like (sutura squamosa), *e.g.* in the squamoso-parietal suture; or by rough opposed surfaces (sutura harmonia), *e.g.* in the suture between the palate plates of the superior maxillary bones. There is one variety of synarthrosis which, in the adult, can scarcely be called a suture, although the differences are of minor importance, viz. **schindylesis**, which is an articulation between the edge of a plate-like bone, such as the rostrum of the sphenoid, and the cleft in another, such as the vomer.

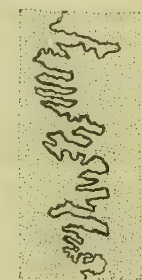


Fig. 195.—Sutura Serrata.

Synchondrosis.—Illustrations of this group can only be found in the young growing individual, because as age advances, and growth ceases, the process of ossification affects the hyaline cartilage which constitutes the uniting medium, and the plane of articulation disappears. Under this heading we may include the planes of junction between all epiphyses and the shafts or diaphyses to which they severally belong. The occipito-sphenoid (Fig. 194), and the petro-jugular articulations in the base of the skull provide other well-marked examples.

MOVABLE JOINTS.

The leading features of this group are capability of **movement** and **permanence**. In very few instances do such joints ever become obliterated under normal conditions. Determining their permanence, and regulating the amount of possible movement, there is always more or less of interruption in the continuity of the structures which bind the osseous elements together. That is, there is always some evidence of a joint cavity, although as a matter of course such interruption can never be so extensive as to entirely disassociate the articulating elements. Therefore in all movable joints a new class of structures is found, viz. the **ligaments**, by means of which continuity is maintained even when all the other uniting media have given place to a joint cavity. The further subdivision of this group is founded upon the amount of movement permissible and the extent to which the joint cavity takes the place of the original continuous uniting medium. Thus we obtain the partly movable or **amphiarthroses**, and the freely movable or **diarthroses**.

An **amphiarthrosis** (Fig. 198) presents the following characteristics:—(*a*) partial movement; (*b*) union by ligaments and by an interposed plate or disc of fibro-cartilage, in the interior of which there is, (*c*) an incomplete or partial joint cavity which may be lined by a rudimentary synovial membrane whose function it is to secrete a lubricating fluid, the **synovia** or joint-oil; (*d*) a plate of hyaline

cartilage coating each of the opposing surfaces of the bones concerned. All the joints belonging to this group occur in the mesial plane of the body. It includes the symphysis pubis, the joints between the bodies of the vertebræ, and the joint between the manubrium sterni and the gladiolus.

A **diarthrosis** (Fig. 196) is the most elaborate as well as the most complete form of articulation. It is characterised by (*a*) capability of movement which is more or less free in its range; (*b*) a reduction of the uniting structures to a series of retaining ligaments; (*c*) a joint cavity which is only limited by the surrounding ligaments; (*d*) the constant presence of **synovial membrane**; (*e*) hyaline encrusting cartilage which clothes the opposed surfaces of the articulating bones. The majority of the joints in the adult belongs to this group. This series of joints has been subdivided into a number of minor sections, in order to emphasise the occurrence of certain well-marked structural features, or because of the particular nature of the movement by which they are characterised. Although in all diarthroses there is a certain amount of *gliding* movement between the opposed surfaces of the bones which enter into their formation, yet, when this gliding movement becomes their prominent feature, as in most of the joints of the carpus and tarsus, they are termed **arthrodia**. But bones may be articulated together so as to permit of movement in one, two, or more fixed axes of movement, or in modifications of these axes. Thus in **uniaxial joints** the axis of movement may lie in the longitudinal axis of the joint, in which case the **rotatory form** of joint results, as in the superior and inferior radio-ulnar articulations; or it may correspond with the transverse axis of the articulation, as in the elbow-joint and knee-joint, when the **ginglymus** or **hinge variety** results. If movement takes place about two principal axes situated at right angles to each other, as in the radio-carpal joint, the terms **biaxial** or **condyloid** are applied. Movements occurring about three principal axes placed at right angles to each other, or in modifications of these positions, constitute **multiaxial joints**, in which the associated structural peculiarities provide the alternative terms of **enarthrodial** or **ball-and-socket joints**.

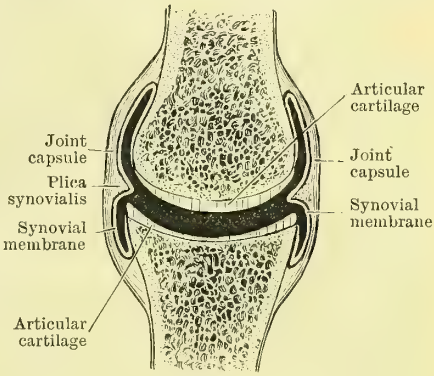


Fig. 196.—Diagram of a Diarthrodial Joint.

STRUCTURES WHICH ENTER INTO THE FORMATION OF JOINTS.

The structures which enter into the formation of joints vary with the nature of the articulation. In every instance there are two or more skeletal elements, whether bones or cartilages, and in addition there are the uniting media, which are either simple or elaborate according to the provision made for rendering the joint more or less rigid or capable of movement. We have already seen that the uniting medium in **synarthrodial joints** is a remnant of the common matrix, whether fibro-vascular membrane or hyaline cartilage, in which ossification has extended from separate centres. Among the **amphiarthroses** there is still extensive union between the opposing surfaces of the articulating bones, but the character of the uniting medium has advanced from the primitive embryonic tissue to fibrous and fibro-cartilaginous material, as well as hyaline cartilage. These, with very few exceptions, are permanent, non-ossifying substances, such as may be seen between the opposing osseous surfaces of two vertebral bodies. The joint cavity, more or less rudimentary, is confined to the centre of the fibro-cartilaginous plate, and may result from the softening or imperfect cleavage of the central tissue. It may also present rudiments of a synovial membrane.

In the **diarthrodial group** the extensive cavity has produced great interruption in the continuity of the uniting structures which originally existed between the bones forming such a joint. Ligaments have therefore additional importance in this group, for not only do they constitute the uniting media which bind the

articulating bones together, but to a large extent they form the peripheral boundary of the joint cavity, although not equally developed in all positions. Thus every diarthrodial joint possesses a fibrous or ligamentous envelope or **capsule** which is attached to the adjacent ends of the articulating bones. For special purposes, particular parts of the capsule may undergo enlargement and thickening, and so constitute strong ligamentous bands, although still forming continuous constituents of the capsule.

Within the capsule a series of intracapsular structures are present. Thus the capsule itself is always lined by a **synovial membrane**, which is continued from the inner surface of the capsule to the surface of the intracapsular portion of each articulating bone. The part of the bone included within the capsule consists of a "non-articular" portion covered by synovial membrane, and an "articular" portion covered by encrusting hyaline cartilage. The latter provides the surface which comes into apposition with the corresponding area of another bone. In its general disposition the synovial membrane may be likened to a cylindrical tube open at each end.

Certain diarthroses present additional intracapsular structures which may be distinguished as interarticular ligaments and interarticular fibro-cartilages.

Interarticular ligaments extend between and are attached to non-articular areas of the intracapsular portions of the articulating bones. They usually occupy the long axis of the joint, and occasionally they widen sufficiently to form partitions which divide the joint-cavity into two compartments, *e.g.* the costo-central, and certain of the chondro-sternal joints.

Interarticular fibro-cartilages or **menisci** (Fig. 197) are more or less complete partitions situated between and separating opposing articular surfaces, and when complete they divide the joint cavity into two distinct compartments. By its periphery, a meniscus is rather to be associated with the joint capsule than with the articulating bones, although its attachments may extend to non-articular areas on the latter.

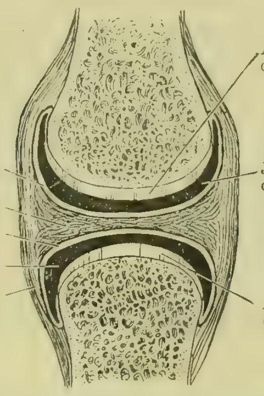


FIG. 197.—DIAGRAM OF A DIARTHRODIAL JOINT WITH AN INTERARTICULAR MENISCUS DIVIDING THE JOINT-CAVITY INTO TWO COMPARTMENTS.

Both interarticular ligaments and menisci have their free surfaces covered by synovial membrane.

Adipose tissue forming pads of varying size is usually found in certain localities within the joint, between the synovial membrane and the surfaces which it covers. These pads are soft and pliable, and act as packing material, filling up gaps or intervals in the joint. During movement they adapt themselves to the changing conditions of the articulation.

In addition to merely binding together two or more articulating bones, ligaments perform very important functions in connexion with the different movements taking place at a joint. They do not appreciably lengthen under strains, and thus ligaments may act as inhibitory structures, and by becoming tense may restrain or check movement in certain directions.

Synovial membranes, in the form of closed sacs termed **synovial bursæ**, are frequently found in other situations besides the interior of joints. Such bursæ are developed for the purpose of reducing the friction, (*a*) between the integument and certain prominent subcutaneous bony projections, as, for instance, the point of the elbow, or the front surface of the patella (subcutaneous synovial bursæ); (*b*) between a tendon and some surface, bony or cartilaginous, over which it plays (subtendinous synovial bursæ); (*c*) between a tendon or a group of tendons and the walls of osteo-fascial tunnels, in which they play (thecal synovial bursæ). Subtendinous synovial bursæ are often placed in the neighbourhood of joints, and in such cases it not infrequently happens that there is a direct continuity between the bursa and the synovial membrane which lines the cavity of the joint through an aperture in the joint-capsule.

THE DIFFERENT KINDS OF MOVEMENT AT JOINTS.

Reference has already been made to the existence of fixed axes of movement as a basis for the classification of certain forms of diarthrodial joints. Hence it is evident that the movements which are possible at any particular joint depend to a large extent upon the shape of its articular surfaces as well as upon the nature of its various ligaments. Therefore the technical terms descriptive of movements either indicate the directions in which they occur, or else the character of the completed movement.

In the great majority of articulations between short bones, the amount of movement is so restricted, and the displacement of the opposing articular surfaces so slight, that the term **gliding** sufficiently expresses its character.

A **gliding** movement of an extensive kind, for example that of the patella upon the femur, in which the movement largely resembles that of the tyre of a wheel revolving in contact with the ground so that different parts are successively adapted to each other, is called **co-aptation.**

Articulations between long bones, on the other hand, are usually associated with a much freer range of movement, with a corresponding variety in its character. **Rotation** is a movement about an axis which is longitudinal. Sometimes it is the only form of movement which a joint possesses; at other times it is merely one of a series of movements capable of execution at the same joint. **Flexion** or bending is a movement in which the formation of an angle between two parts of the body is an essential feature. As it is possible to perform this movement in relation to two axes, viz. a transverse and an antero-posterior axis, it is necessary to introduce qualifying terms. Thus, when two anterior or ventral surfaces are approximated, as at the hip-, elbow-, or wrist-joints, the movement is called **ventral, anterior,** or **palmar flexion**; but if posterior or dorsal surfaces be approximated by the process of bending, then the flexion becomes **posterior** or **dorsi-flexion**, as at the knee- or wrist-joints. Further, at the wrist-joint, the formation of an angle between the ulnar border of the hand and the corresponding aspect of the forearm, produces **ulnar flexion**, and similarly the bending of the hand towards the radial border of the forearm is **radial flexion.**

Extension or straightening consists in obliterating the angle which resulted from flexion. In the case of certain joints, therefore, such as the elbow, wrist, and knee, the segments of the limb occupy a straight line as regards each other when extended.[1]

At the ankle-joint the natural attitude of the foot is flexion at a right angle to the leg. The diminution of this angle by approximating the dorsum of the foot towards the front of the leg constitutes *flexion*; while any effort at placing the foot and leg in a straight line, *i.e.* obliteration of the angle, as in pointing the toes towards the ground and raising the heel, constitutes *extension.*

Abduction is a term which either expresses movement of an entire limb, in a direction away from the mesial plane of the body, or of a digit, away from the plane of the middle finger in the hand, or the plane of the second toe in the case of the foot.

Adduction is the reverse of the foregoing, and signifies movement towards the mesial plane of the body, or towards the planes indicated for the digits of the hand and foot.

Circumduction is a movement peculiarly characteristic of multiaxial or ball-and-socket joints. It consists in combining such angular movements as flexion, extension, abduction, and adduction, so as to continue the one into the other, whereby the joint forms the apex of a cone of movement, and the free end of the limb travels through a circle which describes the base of this cone.

THE DEVELOPMENT OF JOINTS.

Just as the question of structure determines to a large extent the presence or absence of movement in joints, so in tracing their development it will be found that the

[1] From this it will be seen that the term "over-extension" is not a correct expression, and consequently should not be employed.

manner of their appearance forecasts their ultimate destination as immovable or movable arrangements.

All joints arise in mesodermic tissue which has undergone more or less differentiation.

When this differentiation has produced a continuous membranous layer, in which ossific centres representing separate skeletal segments make their appearance, we get the primitive form of suture. The plane of the articulation merely indicates the limit of the ossific process extending from different directions. If, again, the differentiation of the mesoblast has resulted in the formation of a continuous cartilaginous layer, in which ossification commences at separate centres, the plane of the articulation is marked out by the unossified cartilage—in other words, the articulation is a synchondrosis. Ultimately this disappears through the extension of the process of ossification.

To some extent sutures also disappear, although their complete obliteration is not usual even in aged people. Developmentally, therefore, synarthroses or immovable joints do not present any special structural element, and, speaking generally, they have only a temporary existence.

The development of all movable joints is in marked contrast to that of synarthroses. Not only are they permanent arrangements so far as concerns normal conditions, but they never arise merely as planes which indicate the temporary phase of an ossific process. From the outset they present distinct skeletal units, from which the special structures of the joint are derived.

The primitive movable joint is first recognised as a mass of undifferentiated mesodermic cells situated between two masses, which have differentiated into primitive cartilage.

The cell-mass which constitutes the joint-unit presents the appearance of a thick cellular disc, the proximal and distal surfaces of which are in accurate apposition with the primitive cartilages, while its circumference is defined from the surrounding mesoderm by a somewhat closer aggregation of the cells of which the disc is composed. From this cellular disc or joint-unit, all the structures characteristic of amphiarthrodial and diarthrodial joints are ultimately developed.

Thus by the transformation of the circumferential cells into fibrous tissue, the investing ligaments are produced. Within the substance of the disc itself, a transverse cleft, more or less well-defined and complete, makes its appearance. In this manner the disc is divided into proximal and distal segments, separated from each other by an interval which is the primitive joint-cavity. This cleft, however, never extends so far as to interrupt the continuity of the circumferential part of the disc which develops into the fibrous tissue of the investing ligaments. From the proximal and distal segments of the articular disc, the various structures, distinctive of movable joints, are developed.

Thus, in amphiarthrodial joints the cellular articular disc or primitive joint-unit gives origin to the following structures:—From its circumference, investing ligaments; from its interior, the fibro-cartilaginous plate or disc in which an imperfect joint-cavity with corresponding imperfect synovial may be found.

In the case of a diarthrodial joint the changes take place on a more extended scale. The joint-cavity becomes a prominent feature, in relation to which, the surrounding fibrous structures form an investing capsule, lined by a synovial membrane.

When a single cleft arises, but does not extend completely across the longitudinal axis of the articular disc, the undivided portion develops into fibrous interarticular ligaments. On the other hand, when two transverse clefts are formed, that portion of the cellular disc which remains between them becomes transformed into a fibro-cartilaginous interarticular disc or meniscus, which in its turn may either be complete or incomplete, and thus we may obtain two distinct synovial joint cavities belonging to one articulation.[1]

In considering the development of the synovial membrane, and the surfaces on which it is found in the interior of a joint, it is necessary to keep clearly in mind that a synovial membrane is a highly specialised structure, whose function it is to secrete a lubricating fluid or synovia, and that, therefore, its position is determined by the essential necessity of proximity to a direct blood supply. In other words this condition of secretion is provided by all parts of the interior of a joint-cavity except the articular encrusting cartilage. Consequently synovial membrane is only absent from the free surface of articular cartilage.

[1] From a series of observations upon the development of diarthrodial joints, the writer considers that there is evidence to show that the "cellular articular disc" is directly responsible for the production of the epiphyses which adjoin the completed joint cavity, and that, among such amphiarthroses as exist between the bodies of vertebræ, not only the intervertebral disc, but the proximal and distal epiphyses which ultimately unite with the vertebral bodies have a common origin in the joint-unit.

It is not necessary to suppose that the synovial membrane has disappeared from these articular cartilages as the result of friction, because, notwithstanding constant friction, such parts as the interior of capsular ligaments or the semilunar cartilages of the knee-joint have not been denuded of their synovial covering.

MORPHOLOGY OF LIGAMENTS.

From what has been said in connection with the development of joints, it will be evident that ligaments are essentially products derived from the cellular articular disc.

Nevertheless, in relation to the fully-formed joint, many structures are described as ligaments, which do not take origin in the manner just indicated. Some of these ligamentous structures remain fairly distinct from the capsular ligaments with which they are immediately associated; others become thoroughly incorporated with the capsular ligaments and cannot be separated therefrom, while yet others may be found situated within the capsule of a joint, and thus play the part of interarticular ligaments.

Instances of each of these forms of adventitious ligaments may be readily given. For example, we may instance the expansion of the tendon of the semimembranosus muscle to the posterior ligament of the knee-joint, and the offshoots from the tendon of the tibialis posticus muscle to the plantar aspects of various tarsal bones, as illustrations of structures which play an important part as ligaments, but are not indelibly incorporated with the joint capsule.

Of structures which have become indelibly incorporated with the primitive capsule, we may instance the broad tendinous expansions of the quadriceps extensor muscle around the knee-joint.

The internal lateral ligament of the same joint is regarded as a detached portion of the tendon belonging to that part of the adductor magnus muscle which takes origin from the ischium, while the external lateral ligament of the knee is considered by some to be the primitive femoral origin of the peroneus longus muscle. Another illustration of the same condition is found in the coraco-humeral ligament, which is regarded by some as representing a detached portion of the pectoralis minor muscle.

Two illustrations may be given of structures playing the part of ligaments within the capsule of a joint, although in the first instance they are not developed as ligaments. It is questionable if the ligamentum teres of the hip-joint is an interarticular ligament in the true sense of the term; it has been regarded as the isolated and displaced tendon of the ambiens muscle found in birds. In the shoulder-joint, many observers look upon the superior gleno-humeral ligament as representative of the ligamentum teres.

Such structures as the stylohyoid ligament and the internal lateral ligament of the temporo-mandibular joint, although described as ligaments, are in reality skeletal parts which have not attained their complete ossific development.

Again, certain portions of the deep or muscular fascia of the body which become specialised into restraining and supporting bands (*e.g.* the ilio-tibial band of the fascia lata; the stylo-mandibular ligament; the anterior and posterior annular ligaments of the wrist-joint; the anterior, inner, and outer annular ligaments of the ankle-joint), although called ligaments, have no direct developmental association with articular ligaments.

Lastly, the ligament of Poupart and the ligament of Gimbernat, being special developments in connection with an expanded tendon or aponeurosis, are still further removed from association with an articulation.

LIGAMENTS OF THE VERTEBRAL COLUMN AND SKULL.

All vertebræ, with the exception of those which deviate from the common vertebral type, present two sets of articulations whose various parts are arranged upon a uniform pattern. Thus every pair of typical vertebræ presents an articulation between the centra, termed **intercentral**, and a pair of articulations between the neural arches, called **interneural**. With the latter there are associated various important accessory ligaments which bind together laminæ, spinous processes, and transverse processes.

Intercentral Articulations.—These are amphiarthrodial joints. Singly, they present only a slight degree of mobility, but when this amount of movement is added to that of the whole series, the range of movement of the spine becomes considerable. The articular surfaces are the flattened surfaces of adjacent vertebral bodies. They are bound together by the following structures:—

Intervertebral Discs (fibro-cartilagines intervertebrales, Fig. 198).—Each disc accommodates itself to the space it occupies between the two vertebral bodies, to both of which it is firmly adherent. The discs, from different parts of the spinal column, vary in vertical thickness, being thinnest from the third to the seventh dorsal vertebra, and thickest in the lumbar region. In the cervical and lumbar regions each disc is thicker in front than behind, thereby assisting in the production of the

anterior convexity which characterises the spinal column in these two regions. In the dorsal region the discs are thinnest on their anterior aspects in correspondence with the anterior concavity of this section of the spine.

Each disc consists of a circumferential portion (annulus fibrosus), formed for

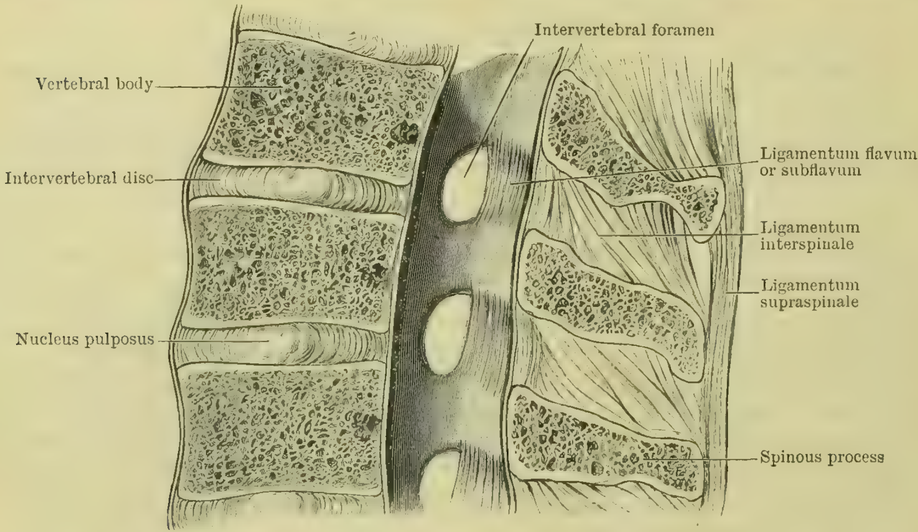


FIG. 198.—MESIAL SECTION THROUGH A PORTION OF THE LUMBAR PART OF THE SPINE.

the most part of oblique parallel fibres running from one vertebra to the other. Horizontal fibres are also found. The axial or central part of the disc is elastic, soft, and pulpy (nucleus pulposus).[1]

The upper and lower surfaces of the disc are closely adherent to the adjoining

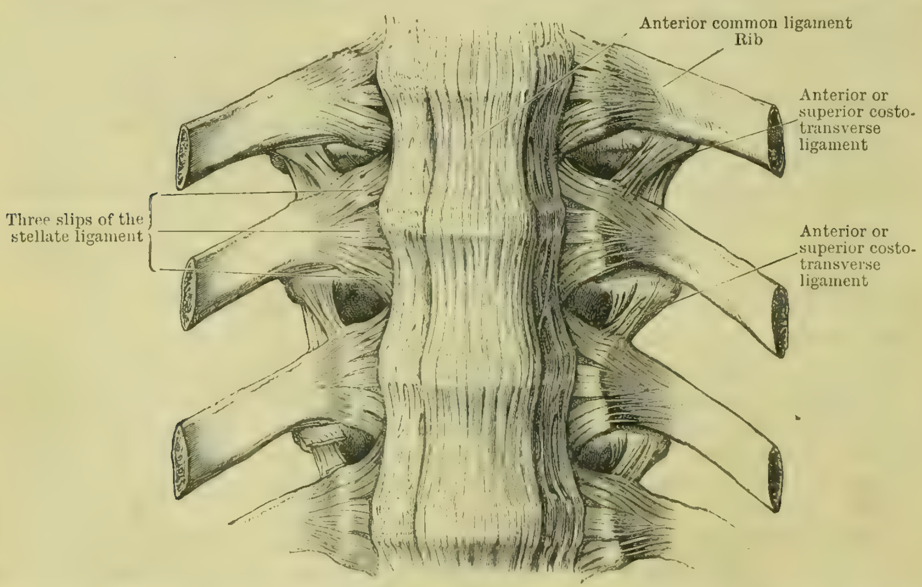


FIG. 199.—ANTERIOR COMMON LIGAMENT OF THE VERTEBRAL COLUMN, AND THE COSTO-VERTEBRAL JOINTS AS SEEN FROM THE FRONT.

epiphyseal plates of the vertebral bodies, and as ossification advances, the distinction between epiphyseal plates and vertebral body disappears.

As a rule the transverse diameter of the disc corresponds to that of the vertebral bodies which it joins together; but in the cervical region, where the lower

[1] This pulpy substance does not present a joint cavity, but in certain cases it is more or less divided by fissures which occupy a transverse horizontal direction.

margin of the superimposed vertebra is overlapped on each side by the one which bears it, the disc does not extend to the extreme lateral margin, and in this position a small diarthrosis may be seen at each lateral margin of the disc.

The **anterior common ligament** (lig. longitudinale anterius, Fig. 199) consists of a wide stratum of longitudinal fibres which extends from the front of the axis vertebra to the front of the upper segment of the sacrum, and becomes gradually wider from above downwards. It lies in front of the intervertebral discs, to which it is firmly attached as it passes from one vertebra to the other. Its fibres vary in length. Some are attached to contiguous margins of two adjoining vertebræ; others pass in front of one vertebra to be attached to the next below, and yet others find their lower attachment three or four vertebræ below the one from which they started. None of the fibres are attached to the transverse depression on the front of a vertebral body.

The **posterior common ligament** (lig. longitudinale posterius, Fig. 200) is found within the spinal canal upon the posterior aspect of the vertebral bodies. It consists of longitudinal fibres, and it extends from the back of the sacrum to the axis vertebra, superior to which it is continued to the skull as the posterior occipito-axial ligament. Opposite each intervertebral disc it is attached to the entire width of the adjacent margins of the two vertebral bodies, its fibres being continued over the posterior surface of the disc. In the lumbar and dorsal regions, the width of the ligament is considerably reduced opposite the back of each vertebral body, and thus it forms a series of dentate projections along both of its margins; but in the cervical region the width of the ligament is more uniform.

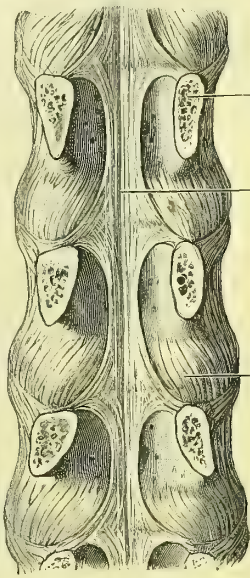


FIG. 200.—POSTERIOR COMMON LIGAMENT OF THE VERTEBRAL COLUMN.

One or two large thin-walled veins escape from the body of each vertebra under cover of this ligament.

Interneural Articulations.—The neural arch of each typical vertebra carries two pairs of articular processes, by means of which it articulates with adjacent neural arches. The articulations between these processes are true diarthroses of the arthrodial variety.

The distinctive characters of these articular surfaces, as regards their shape and direction in the different groups of vertebræ, have been referred to in the section on osteology.

All these articulations are provided with complete but very thin-walled **capsules** (capsulæ articulares), which are thinnest and loosest in the cervical region, where also the movements are freest. Each capsule is lined by a **synovial membrane.**

Associated with these interneural joints are certain ligaments which are accessory to the articulations, although they are quite distinct from the capsule.

The laminæ of adjoining vertebræ are bound together by the **ligamenta subflava** (ligamenta flava vel subflava, Fig. 201), which consist of yellow elastic fibres. The ligamenta subflava close the spinal canal in the intervals between the laminæ. Each ligament is attached superiorly to the anterior aspect of one lamina at a short distance above its lower border, and inferiorly it is attached to the posterior aspect of the subjacent lamina.

In the dorsal region, where the imbrication of adjoining laminæ is a prominent feature, these ligaments are not so distinctly visible from behind as they are in the regions where imbrication of the laminæ is not so marked.

Laterally they extend as far as the articular capsules, while mesially the margins of the ligaments of opposite sides meet under cover of the root of the spinous process.

Contiguous pairs of spinous processes are also attached to each other by **interspinous ligaments** (ligamenta interspinalia, Fig. 198). These are strongest in the

lumbar, and weakest in the dorsal region. Each consists of layers of obliquely interlacing fibres which spring from near the tips of the two adjacent spines and radiate to their opposing margins. In the antero-posterior direction they extend from the base to the tip of the spinous process.

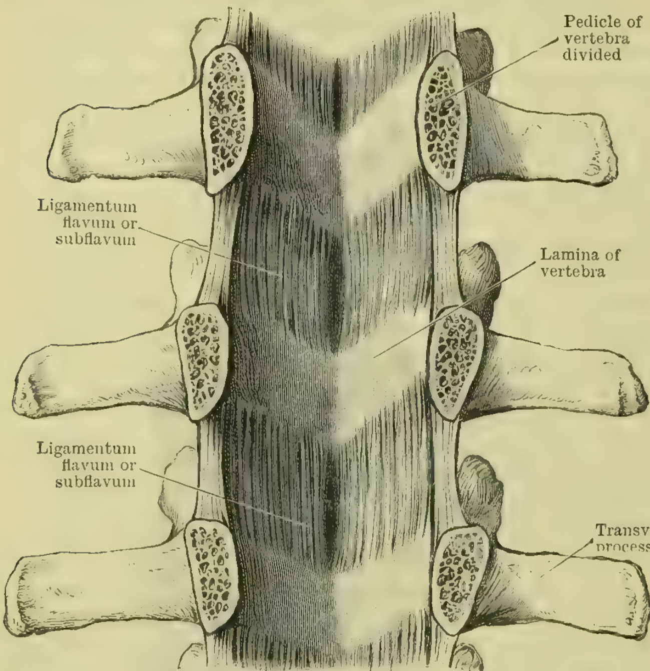


FIG. 201.—LIGAMENTA SUBFLAVA AS SEEN FROM THE FRONT AFTER REMOVAL OF THE BODIES OF THE VERTEBRÆ BY SAWING THROUGH THE PEDICLES.

The **supraspinous ligaments** (ligg. supraspinalia, Fig. 198) consist of longitudinal bands of fibres of varying lengths. They extend from spine to spine, being attached to their tips, and are situated superficial to, although in continuity with, the interspinous ligaments.

In the cervical region this series of ligaments is extensively developed, where they project backwards from the spinous processes between the muscles of the two sides of the neck in the form of an elastic partition called the **ligamentum nuchæ.**

The antero-posterior extent of the ligamentum nuchæ increases as it approaches the occiput, where it is attached to the occipital crest from the external occipital protuberance to the posterior border of the foramen magnum. Its posterior margin is free, and extends from the external occipital protuberance to the spine of the vertebra prominens.

Between the transverse processes there are **intertransverse ligaments** (ligg. intertransversaria), which consist of vertical fibres extending from the postero-inferior aspect of one transverse process to the superior margin of that next below. These ligaments are generally absent from the cervical and upper dorsal regions.

Sacro-coccygeal Joint.—The last piece of the sacrum is joined to the first piece of the coccyx by an intervertebral disc, and the junction is rendered more secure by the presence of certain strong ligaments. An **anterior ligament** (lig. sacro-coccygeum anterius), continuous with the anterior common ligament, is placed in front. A **posterior ligament** (lig. sacro-coccygeum posterius), which stretches downwards from the sharp border of the lower opening of the sacral canal, strengthens the joint behind. A **lateral ligament** (lig. sacro-coccygeum laterale) supports the joint on each side, whilst strong bands pass between the cornua of the two bones and constitute the **interarticular ligaments.**

Inter-coccygeal Joints.—So long as they remain separate, the different pieces of the coccyx are joined by intervertebral discs and by anterior and posterior ligaments.

Movements of the Vertebral Column.—Although the amount of movement permissible between any two vertebræ is extremely limited, yet the total range of movement capable of being attained by the entire vertebral column is very considerable.

Flexion may occur both forwards and backwards at the intercentral articulations, but more freely in the lumbar and cervical regions than in the dorsal region, where the limited amount of intervertebral disc and the imbrication of the laminæ and spines restrict the movement. Backward flexion is most pronounced in the cervical region, and forward flexion in the lumbar region. Between the articular surfaces of the interneural articulations a variety of movements are permitted, dependent upon the directions of these surfaces.

Thus **lateral flexion** is permitted in the lumbar, but not in the cervical or dorsal regions. Again, in the lumbar region **rotation** does not occur, owing to the shape of the articular processes, while it is possible in the dorsal region. In the cervical region the shape and position of the articular surfaces prevent the occurrence both of lateral flexion and of rotation as isolated movements, but a combination of these two movements may take place, whereby rotatory movement in an oblique median axis results. Finally, in the lumbar region, by combining the four forms of flexion, viz. forward, backward, and lateral, a certain amount of **circumduction** is possible.

Articulation of Atlas with Axis.

Between these two vertebræ three diarthroses occur. Two of them are situated laterally in relation to the articular processes, and are called arthrodial diarthroses, because of the flattened nature of the articulating surfaces. The third articulation is mesial in position. It is found between the smooth anterior surface of the odontoid process of the axis and the articular facet on the posterior aspect of the anterior arch of the atlas. This joint is a rotatory diarthrosis.

Ligaments.—Each of the joints is furnished with a **capsular ligament** whereby the joint cavity is circumscribed. In the case of the lateral articulations, each capsular ligament presents a distinct band, named the **accessory ligament**, which is

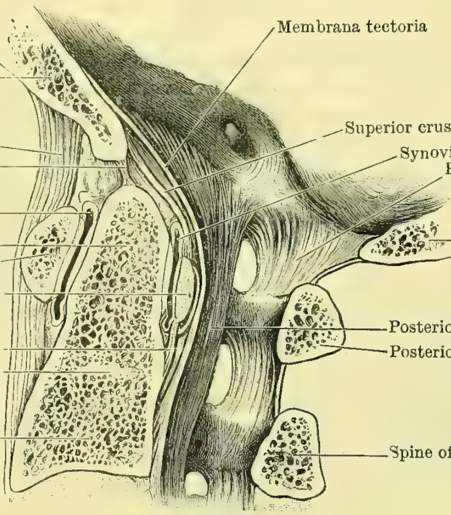


Fig. 202.—Mesial Section through the Occipito-atloid and Atlo-axoid Joints.

situated within the neural canal (Fig. 203), and passes downwards and inwards from the lateral mass of the atlas to the superior aspect of the body of the axis.

The following additional ligaments constitute the leading bonds of union :—

The **anterior atlo-axoid ligament** (Fig. 202) is a membranous structure which is thin laterally, but strong mesially where it is thickened by a prolongation of the anterior common ligament. It extends from the anterior arch of the atlas to the front of the body of the axis.

The **posterior atlo-axoid ligament** (Fig. 202) occupies the position which is elsewhere taken by the ligamenta subflava. It extends from the posterior arch of the atlas to the upper border of the neural arch of the axis.

The **transverse ligament of the atlas** (lig. transversum atlantis, Figs. 202 and 203) is a strong band, placed transversely, which arches backwards behind the neck of the odontoid process of the axis. By its extremities it is attached to the tubercle on the inner aspect of each lateral mass of the atlas. A thin plate of fibro-cartilage is developed in its central part.

Synovial membrane lines each of the three capsular ligaments, and in addition a synovial sac is developed between the odontoid process and the transverse ligament. This is more extensive than the synovial cavity between the odontoid process and the atlas.

Articulation of Spine with Cranium.

There are two articulations between the atlas and the occiput. Each is a diarthrosis in which movement takes place in relation to two axes, viz. the transverse and the antero-posterior. The condyle of the occiput being biconvex, fits into the biconcave superior articular surface of the atlas, while the long axes of the two joints are directed horizontally forwards and inwards.

Ligaments.—Each articulation is provided with a **capsular ligament** which is thin but complete. It is attached to the rough non-articular surfaces surrounding the articular areas on the atlas and occiput.

The following supplementary ligaments are the chief structures which bind the atlas to the occiput:—

The **anterior occipito-atloid ligament** (membrana atlanto-occipitalis anterior, Fig. 202) is a strong although thin membrane, attached inferiorly to the anterior arch of the atlas, and superiorly to the anterior half of the circumference of the foramen magnum. Laterally it is in continuity with the capsular ligaments, while in the mesial plane, where it extends from the anterior tubercle of the atlas to the basi-occiput, it presents a specially well-defined thickened band which might be regarded as a separate accessory ligament or as the beginning of the anterior common ligament of the vertebræ.

The **posterior occipito-atloid ligament** (membrana atlanto-occipitalis posterior, Fig. 202) is another distinct but still thin membrane which is attached superiorly to the posterior half of the circumference of the foramen magnum, and inferiorly to the upper border of the posterior arch of the atlas. Laterally it also is continuous with the capsular ligaments. On each side of the mesial plane its inferior border is arched in relation to the vertebral groove, and is therefore to some extent free, in order to permit the passage of the posterior primary division of the first cervical nerve and the vertebral artery. Not infrequently this arched border becomes ossified, thus converting the groove in the bone into a foramen.

Synovial membrane lines each of the capsular ligaments. There is no direct articulation between the axis and the occiput, but union between them is effected by means of the following accessory ligaments.

The **posterior occipito-axoid ligament** (membrana tectoria, Fig. 203) is situated within the neural canal, and is usually regarded as the upward continuation of the posterior common ligament of the vertebral bodies. It extends from the posterior

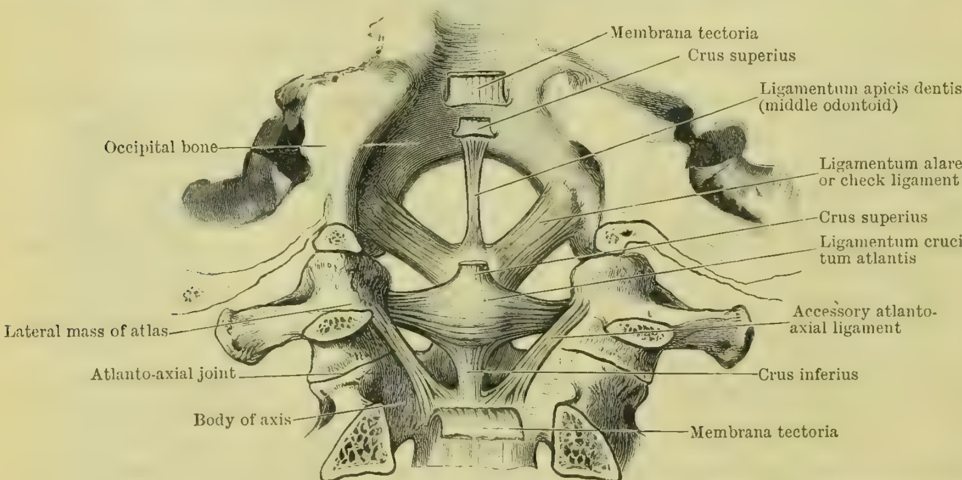


Fig. 203.—Dissection from behind of the Ligaments connecting the Occipital Bone, the Atlas, and the Axis with each other.

surface of the body of the axis to the basilar groove on the upper surface of the basi-occipital bone, spreading laterally on the circumference of the foramen magnum. Some of its deepest fibres are attached to the atlas immediately above the atlo-axoid articulation.

Subjacent to the preceding ligament there is the **ligamentum cruciatum atlantis** (Fig. 203), a structure which is very closely associated with the lig. transversum atlantis. It consists of a *crus transversum,* formed by the superficial fibres of the transverse ligament of the atlas; a *crus inferius,* consisting of mesial longitudinal fibres which are attached below to the posterior surface of the body of the axis, and above to the crus transversum and a *crus superius,* also mesial and longitudinal, whose fibres extend from the crus transversum upwards to the posterior surface of the basi-occiput, immediately subjacent to the posterior occipito-axoid ligament.

The **check ligaments** or **lateral odontoid ligaments** (ligamenta alaria, Fig. 203) are two very powerful, short, and somewhat rounded bands. They are attached mesially to the sides of the summit of the odontoid process, and laterally to the tubercle on the inner aspect of the condylar portions of the occipital bone, viz. the ex-occipital bones.

The **middle odontoid ligament** (ligamentum apicis dentis, Fig. 203) consists of fibres running vertically upwards from the apex of the odontoid process to the mesial part of the anterior margin of the foramen magnum. This ligament to some extent represents an intervertebral disc, in the centre of which, remains of the notochord may be regarded as present.

Even in advanced life a small lenticular mass of cartilage, completely surrounded by bone, persists in the plane of fusion between the odontoid process and the body of the axis.

Movements at these Joints.—At the joints between occiput and atlas the movements are very simple, and consist essentially of movements whereby the head is elevated and depressed upon the vertebral column (nodding movements). In addition a certain amount of oblique movement is possible, during which great stability is attained by resting the front and hinder parts of opposite condyles upon corresponding parts of the atlas.

The head and the atlas rotate together upon the axis, the pivot of rotation being the odontoid process, and the amount of rotation is limited by the check ligaments. No rotation can occur between the occiput and atlas, and stability between atlas and axis is best attained after a slight amount of rotation, similar to the oblique movement between occiput and atlas.

TEMPORO-MANDIBULAR JOINT.

This joint is an arthrodial **diarthrosis.** It occurs between the articular part of the glenoid fossa of the temporal bone and the condylar head of the mandible. These two articular surfaces are markedly dissimilar both in size and shape. In its general outline the articular surface of the head of the mandible is cylindrical, having its long axis directed from within outwards and forwards. On the other hand, the articular part of the glenoid fossa in front of the Glaserian fissure is concavo-convex from behind forwards. Its articular surface includes the eminentia articularis, the eminence at the base of the anterior root of the zygoma. The articular surfaces of the bones are clothed by hyaline encrusting cartilage, whilst the joint cavity is divided into an upper and lower part by a meniscus of fibro-cartilage.

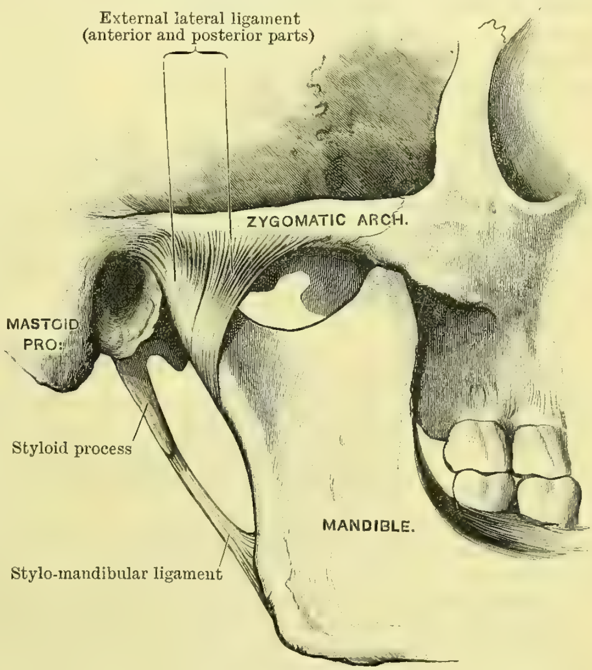


Fig. 204.—Temporo-Mandibular Joint.

Ligaments.—The joint is invested by a **capsular ligament** which is quite com-

plete, but is very thin on the inner side. The outer wall of the capsule—the **external lateral ligament** (lig. temporo-mandibulare, Fig. 204)—is divisible into anterior and posterior portions which are attached superiorly to the root tubercle and lower border of the zygoma, and inferiorly to the outer side and posterior border of the neck of the mandible. The direction of its fibres is downwards and backwards.

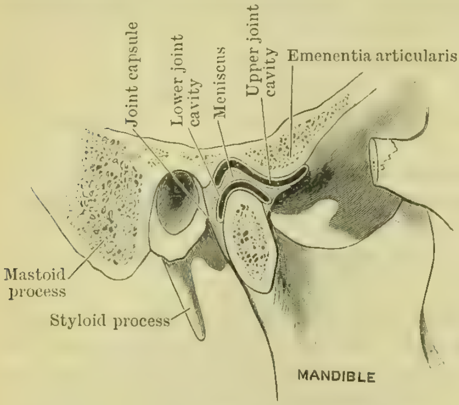


FIG. 205.—SECTION THROUGH THE TEMPORO-MANDIBULAR JOINT.

Within the capsule there is an inter-articular disc or meniscus of fibro-cartilage, the **discus articularis** (Fig. 205), which is moulded upon the condyle of the mandible below, and on the articular surface of the temporal bone above. It thus compensates for the incongruity between the articular surfaces of the two bones. The disc is attached circumferentially to the capsule. It is widest in the transverse direction, thicker behind than in front, and thinnest towards the centre, where it may be perforated. Its anterior margin is intimately associated with the insertion of the external pterygoid muscle.

A **synovial membrane** lines each of the compartments into which the joint cavity is divided by the meniscus. As a rule these membranes are separate from each other, but they become continuous when the disc is perforated. The upper synovial membrane is larger and more loosely disposed than the lower.

Situated on the mesial aspect of the joint, but at a short distance from it, and quite distinct from the capsule, there is an accessory ligament called the **internal lateral ligament** (lig. spheno-mandibulare, Fig. 206). Superiorly it is attached to the spinous process of the great wing of the sphenoid bone, and inferiorly to the lower as well as the hinder border or lingula of the inferior dental foramen. It is not an articular ligament in the true sense, for instead of being connected with the joint, it is developed in the tissue surrounding part of Meckel's cartilage.

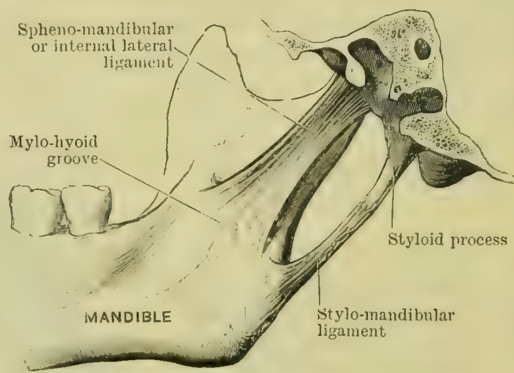


FIG. 206.—INTERNAL LATERAL LIGAMENT OF THE TEMPORO-MAXILLARY JOINT.

Portions of the following structures are found in the interval between the spheno-mandibular ligament and the ascending ramus of the mandible—viz. the external pterygoid muscle; internal maxillary vessels; inferior dental vessels and nerve; middle meningeal vessels; auriculo-temporal nerve; a deep portion of the parotid gland.

Movements of the Mandible.—The nature of the movements which the lower jaw can perform is determined partly by the character of the articular surfaces of the temporo-mandibular joint, and partly by the fact that, while the two joints always act simultaneously, they may also, to some extent, perform the same movement alternately.

When movement takes place through the long or transverse horizontal axis of each joint, the mandible may be elevated, as in clenching the teeth, or it may be depressed, as in gaping. In the latter movement the condyle leaves the glenoid fossa, and, along with the meniscus, it moves forwards until they rest upon the articular eminence. Meantime the chin describes the arc of a circle, of which the centre or point of least movement corresponds to the position of the inferior dental foramen, and thus the structures which enter at that foramen are protected against stretching. Coincidently with the forward movement of the condyle, it glides in a revolving manner upon the inferior aspect of the meniscus.

At any stage in the movement of depressing the chin the mandible may be protruded, so that the inferior incisor teeth are projected in front of the upper set, a movement which results from the condyles of the jaw being drawn forwards upon the articular eminences. A similar

relation of the condyle to the articular eminence occurs during the exaggerated depression of the mandible which results from yawning, in which position the articulation is liable to be dislocated. When the two joints perform the same movement alternately, a certain amount of lateral motion results, from the fact that the long axis of each joint presents a slight obliquity to the transverse axis of the skull, and consequently a grinding or oblique movement in the horizontal plane is produced. Excessive depression, with the risk of dislocation, is resisted by the fibres of the external lateral ligament which becomes tense.

In all movements of the mandible the meniscus conforms closely to the position of the condyle, and they move forwards and backwards together, but at the same time the meniscus does not restrict the movements of the condyle. Thus while the meniscus, along with the condyle, is gliding upon the temporal aspect of the joint, the condyle itself revolves upon the inferior surface of the meniscus.

Cranial Ligaments not directly associated with Articulations.

The **stylo-mandibular ligament** (lig. stylo-mandibulare, Figs. 204 and 206) is a specialised portion of the deep cervical fascia which extends from the anterior aspect of the tip of the styloid process of the temporal bone to the posterior border of the angle of the mandible, between the insertions of the masseter and internal pterygoid muscles.

The **pterygo-spinous ligament** (lig. pterygo-spinosum) is a membrane extending from the upper part of the posterior free margin of the external pterygoid plate, backwards and slightly outwards, to the spinous process of the sphenoid. An interval is left between its upper border and the floor of the skull for the outward passage of those branches of the inferior maxillary nerve which supply the external pterygoid, temporal, and masseter muscles. This ligament has a tendency to ossify either wholly or partially.

The **stylo-hyoid ligament** (lig. stylo-hyoideum), may be regarded as the downward continuation of the styloid process of the temporal bone. Inferiorly it is attached to the lesser cornu of the hyoid bone. It is not infrequently ossified, in which case it constitutes the epihyal bone found in many animals.

THE JOINTS OF THE THORAX.

Costo-vertebral articulations (articulationes costo-vertebrales). The typical rib articulates with the vertebral column both by its head and by its tubercle. Thus, two sets of articulations, with their associated ligaments, exist between the ribs and the vertebræ, but each set is constructed upon a common plan, with the exception of certain joints situated at the upper and lower ends of the series, where the ribs themselves deviate from the typical form.

Costo-Central Joints.

The articulations of the heads of the ribs with the centra or bodies of the vertebræ (articulationes capitulorum, Fig. 199) are all diarthroses, which, from their somewhat hinge-like action, may be classed as ginglymoid.

The head of every typical rib is wedge-shaped, and presents two articular facets, an upper and a lower, separated from each other by an antero-posterior ridge which abuts against an intervertebral disc, while the articular facets articulate with similar surfaces on the contiguous margins of the two vertebræ adjoining the disc. These surfaces form a wedge-shaped depression or cup, the bottom of which is more elastic than the sides, and thus an arrangement is provided which tends to reduce the shock of blows upon the walls of the chest.

Each of these articulations is provided with a **capsular ligament** which surrounds and encloses the joint, and is attached to contiguous non-articular margins on the head of the rib and the two vertebral bodies. On its anterior or ventral aspect the capsule presents three radiating fasciculi which collectively form the **stellate** or **anterior costo-vertebral ligament** (lig. capituli costæ radiatum, Fig. 199). These fasciculi radiate from a centre on the front of the head of the rib, so that the middle fasciculus becomes attached to the intervertebral disc, while

the upper and lower fasciculi proceed to the adjacent margins of the two vertebræ between which the disc is situated, and with which the rib articulates. To a slight extent these radiating fasciculi pass under cover of the lateral margin of the anterior common ligament of the vertebral bodies. In those joints in which the head of the rib does not articulate with an intervertebral disc, the central fasciculus of the stellate ligament is wanting, but the other two retain the same general arrangement.

The **interarticular ligament** (lig. capituli costæ interarticulare) consists of short transverse fibres within the capsule. These are attached, on the one hand, to the ridge which intervenes between the two facets on the head of the rib, and on the other to the lateral aspect of the intervertebral disc. This ligament is not a meniscus, but merely an interarticular ligament, of width sufficient to divide the joint cavity into an upper and a lower compartment. It is absent from those joints which do not articulate with an intervertebral disc, *i.e.* from those ribs which only articulate with the body of one vertebra.

The interarticular ligament is supposed to represent the outer end of a ligament which, under the name of the **lig. conjugale costarum**, connects the heads of the ribs of certain mammals across the posterior aspect of the intervertebral disc, and which, in the human subject, until the seventh month of fœtal life, connects the posterior aspects of the necks of a pair of ribs across the mesial plane.

Synovial membrane lines each joint cavity, and therefore, in all cases where the joint is divided into two compartments, each one has its own synovial membrane.

Costo-Transverse Joints.

The tubercle of each *typical* rib articulates with the transverse process of the lower of the two dorsal vertebræ with which the head of the rib is associated (articulatio costo-transversaria). Near the tip of the transverse process there is an articular facet, on its anterior aspect, for articulation with the corresponding facet on the mesial articular part of the rib tubercle. The joint so formed is an arthrodial diarthrosis.

The joint cavity is surrounded by a comparatively feeble **capsular ligament**, which is attached immediately beyond the margins of the articular facets, and in which no special bands can be distinguished.

A simple **synovial membrane** lines the capsular ligament in all cases where the latter is present.

The following accessory ligaments, in connexion with this joint, strengthen and support the articulation:—

The **anterior** or **superior costo-transverse ligament** (ligamentum costo-transversarium anterius, Fig. 199) consists of strong bands of fibres which are attached to the upper border of the neck of the rib, extending from the head outwards to the non-articular part of the tubercle. All these fibres may be traced upwards. Those situated nearest to the head of the rib proceed obliquely upwards and outwards, to be attached to the transverse process immediately above, but with extensions to the adjoining rib and its costo-transverse capsular ligament. Others proceed almost vertically upwards to the adjoining transverse process, while those which ascend from the upper surface of the tubercle pass obliquely upwards and inwards to reach the postero-inferior aspect of the adjoining transverse process.

The **posterior costo-transverse ligament** (ligamentum costo-transversarium posterius) is a band of transverse fibres applied to the postero-external aspect of the capsule. By one end these fibres are attached to the tip of the transverse process behind its articular facet, and by the other to the external rough surface of the tubercle of the rib.

The **middle costo-transverse ligament** (lig. colli costæ) consists of short fibres which stretch from the posterior aspect of the neck of the rib, backwards and inwards, to the front of the transverse process, but, in addition, a proportion of the fibres passes to the posterior aspect of the inferior articular process of the upper of the two vertebræ with which the head of the rib articulates.

The following exceptions to the general plan of rib-articulation indicated above must be noted:—

1. There is no articulation between the eleventh and twelfth ribs and the transverse processes of the corresponding vertebræ.
2. The superior costo-transverse ligament is wanting from the first rib, and is either rudimentary or wanting in the case of the twelfth rib.
3. The middle costo-transverse ligament is rudimentary in the eleventh and twelfth ribs.

The **ligamentum lumbo-costale** extends from the upper surface of the base of the transverse process of the first lumbar vertebra to the under surface of the neck of the twelfth rib, as well as to the under surface of the transverse process of the twelfth dorsal vertebra.

Articulations between the Ribs and their Cartilages.

Each rib possesses an unossified portion, termed its costal cartilage. As age advances, this cartilage may undergo a certain amount of superficial ossification, but it never becomes entirely transformed. The line of demarcation between bone and cartilage is clear and abrupt, and usually the bone forms an oval cup, in which the end of the cartilage is retained by means of the continuity which exists between the periosteum and the perichondrium. There is no articulation in the proper sense between the rib and its cartilage, although a synovial cavity has occasionally been found between the first rib and its cartilage.

Interchondral Joints.

These articulations are arthrodial diarthroses, and they are found between adjoining margins of certain of the costal cartilages, viz. from the fifth to the eighth or ninth. The cartilages which thus articulate develop flattened, somewhat conical, prolongations of their substance, and thereby the intercostal spaces are interrupted where these flat articular facets abut against each other. Each joint is closed by a surrounding **capsular ligament**, the superficial and deep aspects of which are specially strengthened by **external** and **internal interchondral ligaments.** These bands extend obliquely between adjacent cartilages.

A **synovial membrane** lines each joint-capsule.

Costo-sternal Joints.

The upper seven pairs of costal cartilages, as a rule, extend to the lateral margins of the sternum (articulationes sternocostales). Of these, the first pair is implanted directly upon the manubrium sterni. The ossific process ends abruptly in connexion with the rib, and also ceases as suddenly in connexion with the sternum, and hence the cartilage does not normally present an articulation at either end.

From the second to the seventh pairs of ribs inclusive, the costo-sternal joints are constructed upon the type of arthrodial diarthroses, although, in the case of the sixth and seventh cartilages, the joint-cavity is always small, and is frequently obliterated.

The sternal end of each of these costal cartilages presents a slight antero-posterior ridge which fits into a shallow V-shaped depression upon the lateral margin of the sternum. With the exception of the sixth cartilage, the others articulate opposite the lines of union between the primary segments of the sternum, whereas the sixth articulates upon the side of the lowest segment of the meso-sternum.

Each joint is enclosed by a **capsular ligament**, composed of fibrous tissue, attached to the adjacent borders of the articulating elements. Specially strong fibres distinguish the superficial and deep aspects of the capsule.

The **anterior costo-sternal ligament** (lig. costo-sternalium radiatum, Fig. 207) is composed of strong fibres which radiate from the anterior surface of the costal cartilage, near its sternal end, to the front of the sternum. The ligaments of opposite sides interlace with each other, and so cover the front of the sternum with a felted membrane—the **membrana sterni.**

The **posterior costo-sternal ligament**—also a part of the capsule—has attachments similar to the foregoing, but the arrangement of its fibres is not so powerful.

The **ligamentum costo-xiphoidea** passes from the front of the upper part of the xiphoid cartilage, obliquely upwards and outwards to the front of the seventh, and sometimes to the front of the sixth costal cartilage.

Within the capsules of these joints **interarticular ligaments** (ligg. sterno-costalia interarticularia, Fig. 207) may be found. Their disposition is somewhat uncertain, for

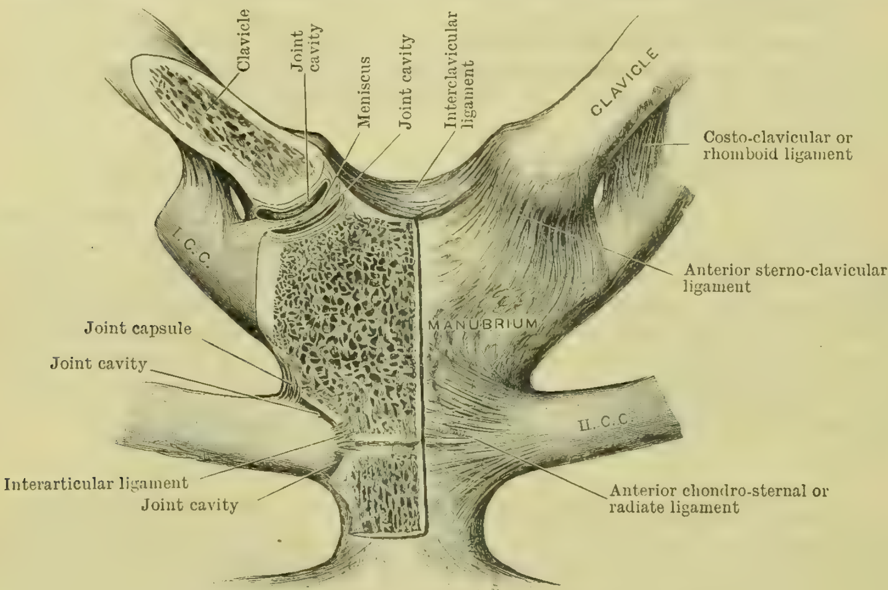


FIG. 207.—STERNO-CLAVICULAR AND COSTO-STERNAL JOINTS.

whereas, in the case of the second pair of cartilages, they invariably divide the joint cavity into two distinct compartments—an upper and a lower—such an arrangement is very uncertain in the other joints, and they occasionally, especially in the cases of the sixth and seventh cartilages, entirely obliterate the joint cavity. These igaments extend horizontally between the ends of the costal cartilages and the side of the sternum.

Synovial membrane is found wherever a joint cavity is developed, and therefore there may be one or two synovial membranes, according to the presence or absence of a proper interarticular ligament. When the joint cavity is obliterated by the fibrous structure which represents the interarticular ligament, a synovial membrane is also absent.

STERNAL ARTICULATIONS.

Primarily the sternum consists of an elongated plate of hyaline cartilage, which becomes subdivided into segments by the process of ossification.

The four segments of which the **gladiolus** is originally composed unite with each other after the manner of typical synchondroses.

Similarly the ensiform cartilage and the gladiolus ultimately become united. It is not usual to find the manubrio-gladiolar joint obliterated by the ossification of the two bony segments. Even in advanced life it remains open, and the joint partakes of the nature of an amphiarthrosis (Fig. 207), although a joint cavity is not found under any circumstances in the plate of fibro-cartilage which intervenes between the manubrium and the gladiolus.

The **membrana sterni**, to which reference has already been made, assists in strengthening the union between the different segments of the sternum.

Movements of the Ribs and Sternum.—These movements may be considered either independently of, or as associated with, respiration.

In the former condition the ribs move in connexion with flexion and extension of the vertebral column, being more or less depressed and approximated in the former, and elevated or

pulled apart in the latter case. Considered in connexion with respiration, it is necessary to observe that, to all intents and purposes, the vertebral column and the sternum are rigid structures. Next we must remember that the heads of all the ribs occupy fixed positions, and similarly the anterior ends of seven pairs of cartilages are fixed to the lateral margins of the sternum. The ribs thus form arches, presenting a large amount of obliquity from behind forwards. Therefore, during inspiration, when the rib is elevated, the arch becomes more horizontal, and the transverse diameter of the chest is increased. At the same time, the anterior ends of the sternal ribs tend to thrust the sternum forwards and upwards; but the nature of the attachment of the first pair of ribs to the sternum, as well as the attachment of the diaphragm to the ensiform cartilage, prevents this movement from becoming excessive, and hence the sternum becomes a line of resistance to the forward thrust of the ribs. As a consequence, the ribs rotate upon themselves about an oblique axis which passes downwards, outwards, and backwards through the capitular joint and the neck of the rib anterior to the costo-transverse joint.

In this way increase, both of the antero-posterior and transverse diameters of the thorax, is provided for, although the amount of increase is not equally pronounced in all planes. Thus at the level of the first rib very little eversion is possible, because the axis of rotation is nearly transverse, and therefore any increase in the transverse or antero-posterior thoracic diameters at this level may be disregarded, although a certain amount of elevation of the manubrium sterni and anterior end of the first rib is evident.

Below the level of the sixth rib elevation and rotation of the rib during inspiration are usually said to be complicated by a certain amount of backward movement, due to the character of the costo-transverse joint, until, in the case of the last two ribs, which are destitute of costo-transverse joints, a movement backwards is almost entirely substituted for elevation. It is probable, however, that the movements of the asternal ribs exactly correspond to those of the sternal series, and that by the contraction of the costal digitations of the diaphragm the anterior ends of the asternal ribs are provided with fixed positions comparable to those supplied by the sternum to the ribs of the sternal series.

We may therefore say that during inspiration the ribs move upwards and outwards between their fixed ends, while as a whole the rib rotates, and its anterior end is thrust slightly forwards. During expiration these movements are simply reversed.

THE ARTICULATIONS OF THE SUPERIOR EXTREMITY.

The bony arch formed by the clavicle and scapula articulates directly with the axial skeleton only at one point, viz. the sterno-clavicular joint.

ARTICULATIONS OF THE CLAVICLE.

The Sterno-clavicular Joint.

The sterno-clavicular joint (articulatio sterno-clavicularis) is an example of an arthrodial diarthrosis. The articular surfaces concerned in its formation present the following appearances:—

1. The sternal end of the clavicle is somewhat triangular in outline, having its most prominent angle directed downwards and backwards. The anterior and posterior sides of the triangle are slightly roughened for the attachment of ligaments, while the base or inferior side is smooth and rounded, owing to the prolongation of the articular surface to the inferior aspect of the bone. In the antero-posterior direction the articular surface tends to be concave, while vertically it is slightly convex.

2. An articular facet, situated on the superior lateral angle of the manubrium sterni, but in a plane slightly behind the supra-sternal notch, articulates with the clavicle. This facet is considerably smaller than the clavicular facet with which it articulates.

3. The superior surface of the first costal cartilage close to the sternum also participates to a small extent in the articulation.

It should be noted that the articular surfaces of the clavicle and sternum are covered mainly by **fibro-cartilage.**

A **capsular ligament** is well marked on all sides except inferiorly, where it is very thin.

The **anterior sterno-clavicular ligament** (Fig. 207) forms part of the capsule, and consists of short fibres which extend obliquely downwards and inwards from the anterior aspect of the sternal end of the clavicle to the adjoining anterior surface of the sternum and the anterior border of the first costal cartilage.

The **posterior sterno-clavicular ligament** also forms part of the capsule, and

consists of similarly-disposed, but not so strong, oblique fibres situated on the posterior aspect of the articulation.

A **fibro-cartilaginous meniscus** (discus articularis, Fig. 207) divides the joint cavity into two compartments. It is nearly circular in shape, and adapts itself to the articular surfaces between which it lies. It is thickest at the circumference and thinnest at the centre, where it occasionally presents a perforation, thereby permitting the two synovial cavities to intercommunicate. By its circumference it is in contact with, and adherent to, the surrounding capsule, but its upper margin is attached to the apex of the articular surface of the clavicle, while by its lower margin it is fixed to the sternal end of the first costal cartilage.

Two **accessory ligaments** are associated with this joint, viz. the interclavicular and the rhomboid.

The **interclavicular ligament** (Fig. 207) is a structure of considerable strength, forming a broad band of fibrous tissue which is attached to the superior rounded angle or apex of the sternal end of the clavicle as well as to the adjacent margins of the articular surface. Its fibres pass across the interclavicular notch to become attached to corresponding parts of the opposite clavicle, but in their course they dip down into the supra-sternal notch, in which many of them are fixed to the sternum. In this way their presence neither bridges nor obliterates the notch between the two clavicles, and the ligament really becomes a superior sterno-clavicular ligament for each joint.

The **rhomboid ligament** (lig. costo-claviculare, Fig. 207) consists of short, strong fibres which are attached inferiorly to the upper surface of the first costal cartilage. They pass obliquely upwards and outwards to a rough impression situated on the lower aspect of the sternal end of the clavicle, and are distinct from the capsular ligament. Occasionally a bursa is found in the interior of this ligament.

As a rule, there are two **synovial membranes** lining the two joint cavities (Fig. 207), separated from each other by the interarticular meniscus. Sometimes, however, the two membranes establish continuity through a perforation in the meniscus.

The Acromio-clavicular or Scapulo-clavicular Joint.

The acromio-clavicular joint (articulatio acromio-clavicularis) is another instance of an arthrodial diarthrosis. It is situated between the acromial end of the clavicle and the inner aspect of the acromion process of the scapula. Each articular surface is an oval, flattened facet, covered by **fibro-cartilage**.

The **ligaments** which surround this small joint form a complete **capsule** (capsula articularis), of which the upper and lower parts are specially strong, and are therefore named the **superior** and **inferior acromio-clavicular ligaments** (Fig. 209). These consist of short fibres passing between the adjacent rough margins of the two bones in the positions indicated by their names.

A **meniscus** (discus articularis), which is nearly always incomplete, and may occasionally be wanting, is usually found within the joint cavity, where it lies obliquely, with its upper margin farther from the mesial plane than its lower margin, and having its borders attached to the surrounding capsule. Frequently the meniscus is wedge-shaped, with its base directed upwards and its apex free.

A **synovial membrane** is found forming either a single or a double sac, according to the condition of the meniscus. Complete division of the joint cavity, however, is rare.

Ligamentum Coraco-claviculare.—Accessory to this articulation there is the strong **coraco-clavicular ligament** which binds the acromial end of the clavicle to the coracoid process of the scapula. It is readily divisible into two parts, viz. the conoid and trapezoid ligaments.

The **conoid ligament** (Fig. 209) is situated internal to and slightly behind the trapezoid. It is narrow and pointed at its inferior end, by which it is attached to the upper aspect of the coracoid process, in close proximity to the supra-scapular notch. Its upper end widens out in the manner expressed by its name, and is attached to the conoid tubercle of the clavicle.

The **trapezoid ligament** (Fig. 209) is attached inferiorly to the upper surface of the posterior half of the coracoid process, external and anterior to the attachment of

the conoid ligament. Superiorly it is attached to the trapezoid ridge on the under surface of the acromial end of the clavicle. Its outer and inner borders are free. Its anterior surface is principally directed upwards, and its posterior surface, to a similar extent, looks downwards.

A **synovial bursa** usually occupies the re-entrant angle between these two ligaments.

Movements at the Clavicular Joints.—The movements of the inner end of the clavicle at the **sterno-clavicular joint** are limited in their range, owing to the tension of the ligaments. When the shoulder is raised or depressed the outer end of the clavicle moves upwards and downwards, whilst its sternal end glides upon the surface of the interarticular meniscus within the joint; when, on the other hand, the shoulder is carried forwards or backwards, the inner end of the clavicle, along with the interarticular meniscus moves upon the sternal facet. In addition to these movements of elevation, depression, forward movement and backward movement of the clavicle, there is also allowed at the sterno-clavicular joint a certain amount of circumduction of the clavicle.

The part which is played by certain of the ligaments in restraining movement requires careful consideration. The **rhomboid ligament** checks excessive elevation of the shoulder, and restrains within certain limits both backward and forward movement of the clavicle. When the clavicle is depressed, as in cases where a heavy weight, such as a bucket of water, is carried in the hand, it receives support by resting upon the first rib, and the tendency for the inner end of the bone to start up out of its sternal socket is obviated by the tension of the **interarticular meniscus**, the **interclavicular ligament**, and the **anterior** and **posterior sterno-clavicular ligaments.**

The **interarticular meniscus** not only acts as a cushion which lessens the shock of blows received upon the shoulder, but it also acts as a most important bond of union, and prevents the inner end of the clavicle from being driven upwards upon the top of the sternum when force is applied to its outer end.

The movements at the **acromio-clavicular joint** are of such a kind as to allow the inferior angle, and to some extent the base of the scapula, to remain more or less closely applied to the chest-wall during the various movements of the shoulder. The strong connexion between the coracoid process and the acromial end of the clavicle, by means of the conoid and trapezoid ligaments, renders it necessary that the scapula should follow the clavicle in its various excursions. The presence of the acromio-clavicular joint, however, enables the scapula to change its position somewhat with reference to the clavicle as the shoulder is moved. Thus, when the shoulder is raised and depressed, a marked difference takes place in the angle between the two bones; again, when the shoulder is thrown forwards or backwards, these movements can be performed without altering in a material degree the direction of the glenoid cavity of the scapula, or in other words, the socket of the shoulder-joint.

The **conoid** and **trapezoid ligaments** set a limit upon the movements of the scapula at the acromio-clavicular joint. They both, but more particularly the trapezoid ligament, prevent the acromion process of the scapula from being carried inward below the outer end of the clavicle when blows fall upon the outer aspect of the shoulder.

Ligaments of the Scapula.

These ligaments are not directly connected with any articulation. The **coraco-acromial ligament** (lig. coraco-acromiale, Fig. 209) completes the arch between the coracoid and acromion processes of the scapula, and thus provides a secondary socket for the greater protection and security of the shoulder-joint. It is a flat triangular structure stretched tightly between its lines of attachment. By its base it is fixed to a varying amount of the postero-external border of the coracoid process, and by its narrower apical end to the tip of the acromion process, immediately external to the acromio-clavicular joint. Its surfaces look upwards and downwards, and its free borders outwards and inwards. It is thinnest in the centre, where it is sometimes perforated by a prolongation of the tendon of the pectoralis minor.

The **suprascapular ligament** (lig. transversum scapulæ superius) is a distinct but short flat band which bridges the notch of the same name. It may be continuous with the conoid ligament, and it is frequently ossified. As a rule the foramen completed by this ligament transmits the suprascapular nerve, while the corresponding vessels travel above the ligament to reach the supraspinous fossa.

A small duplicate of this ligament may often be found bridging the foramen on its ventral aspect, subjacent to which small branches of the suprascapular artery return from the supraspinous to the subscapular fossa.

The **spino-glenoid ligament** (lig. transversum scapulæ inferius) consists of another set of bridging fibres which are situated on the posterior aspect of the

neck of the scapula. By one end they are attached to the external border of the scapular spine, and by the other to the adjacent part of the posterior aspect of the head of the scapula. The suprascapular nerve and vessels pass subjacent to this ligament.

THE SHOULDER-JOINT.

The shoulder-joint (articulatio humeri) is one of the largest as well as the most important of the joints of the upper limb. It is an example of the enarthrodial, *i.e.* ball-and-socket variety of a diarthrosis, and, at the cost of a certain amount of security, it has obtained an extended range of movement.

The bones which enter into its formation are the glenoid fossa of the scapula and the head of the humerus.

The glenoid fossa is a shallow pyriform articular surface, having its narrow end directed upwards and slightly forwards. The upper half of the anterior margin of the fossa is characterised by a shallow notch which accommodates the narrow part of the subscapularis muscle as it runs outwards to its insertion. At the apex of the fossa there is a flat area for the attachment of the long tendon of the biceps flexor cubiti muscle. The head of the humerus is hemispherical and articular, while, external to its articular margin, there is a slight constriction (the anatomical or true neck of the humerus), which is most strongly marked in relation to the greater and lesser tuberosities of the humerus.

Under ordinary conditions the two articular surfaces are maintained in apposition by muscular action, aided by atmospheric pressure, and thus, when the muscles are removed, the bones fall asunder to the full extent of the restraining ligaments. Only a small part of the humeral head is in contact with the glenoid fossa at any particular moment, because the former is much larger than the latter, but, by reason of the shallow character of this fossa, all parts of the two articular surfaces may successively be brought into contact with each other.

In the position of rest, as the limb hangs parallel to the vertical axis of the trunk, the inferior aspect of the neck of the humerus is brought into close relation with the lower part of the glenoid fossa.

The **glenoid ligament** (labrum glenoidale, Fig. 209) deepens the glenoid fossa, and thus extends the articular surface. It is situated within the joint capsule, and to some slight extent increases the security of the articulation. It consists of a strong ring of dense fibrous tissue attached to the free margin of the glenoid fossa. Many of its fibres are short, and pass obliquely from the inner to the outer aspect of the ridge, so that its attached base is broader than its free edge, and therefore in cross section it appears somewhat triangular. The long tendon of the biceps, which arises from the apex of the glenoid fossa, becomes to a considerable extent incorporated with this ligament.

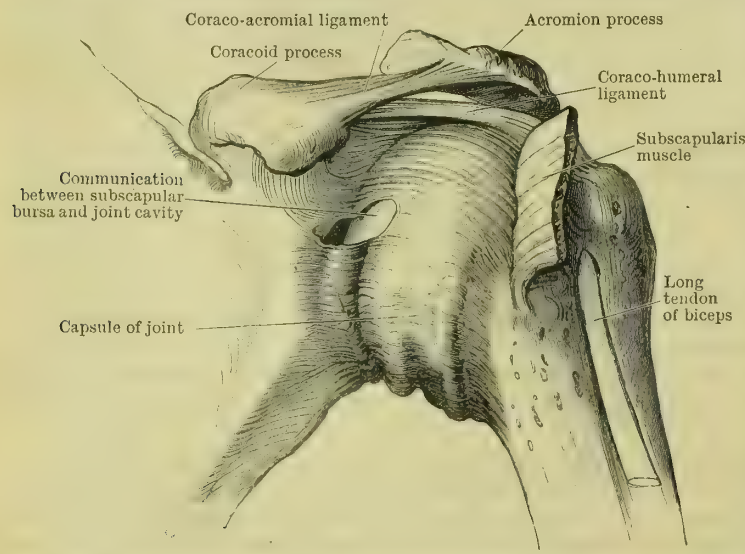


FIG. 208.—CAPSULE OF THE SHOULDER-JOINT AND CORACO-ACROMIAL LIGAMENT.

The **capsular ligament** (capsula articularis, Fig. 208) presents the general shape which is characteristic of the corresponding ligament in other ball-and-socket joints,

viz. a hollow cylinder. By its upper end the capsule is attached to the circumference of the glenoid fossa, external to the glenoid ligament, and also, to a considerable extent, to the glenoid ligament itself.

By its lower end it is attached to the neck of the humerus, and therefore beyond the articular area of the head. The capsule is strongest on its superior aspect, while inferiorly, where the neck of the bone is least defined, it extends downwards for a short distance upon the humeral shaft. Its fibres for the most part run longitudinally, but a certain number of them pursue a circular direction.

A prolongation of the capsule, the **transverse humeral ligament** presenting both longitudinal and transverse fibres, bridges that part of the bicipital groove which is situated between the tuberosities of the humerus. At this point an interruption in the capsule, beneath the transverse humeral ligament, permits the long tendon of the biceps to escape from its interior. In addition to the opening just referred to, there is another very constant deficiency in the upper and anterior part of the capsule, where the narrowing tendon of the subscapularis muscle is brought into contact with a bursa formed by a protrusion of the synovial membrane. This defect in the capsule has its long axis in the direction of the longitudinal fibres. Occasionally there is a similar but smaller opening under cover of the tendon of the infraspinatus muscle. Through the two latter openings the joint cavity communicates with bursæ situated between the capsule and the muscles referred to.

The tendons of the subscapularis, supraspinatus, and infraspinatus muscles fuse with, and so strengthen, the capsule as they approach their respective insertions.

On the superior aspect of the articulation the capsule is augmented by an accessory structure, the **ligamentum coraco-humerale** (Fig. 208). By its inner end, which is situated immediately above the glenoid fossa, but subjacent to the coraco-acromial ligament, it is attached to the external border of the root of the coracoid process, while its outer end is attached to the humeral neck close to the great tuberosity. This ligament forms a flattened band, having its hinder and lower border fused with the capsule, but its anterior and upper margin presents a free edge, slightly raised above the level of the capsule. This structure is believed to represent that portion of the pectoralis minor to which reference has already been made in connexion with the coraco-acromial ligament.

The **coraco-glenoid ligament** is another accessory structure which is not always present. It springs from the coracoid process along with the former ligament, and extends to the upper and hinder margin of the head of the scapula.

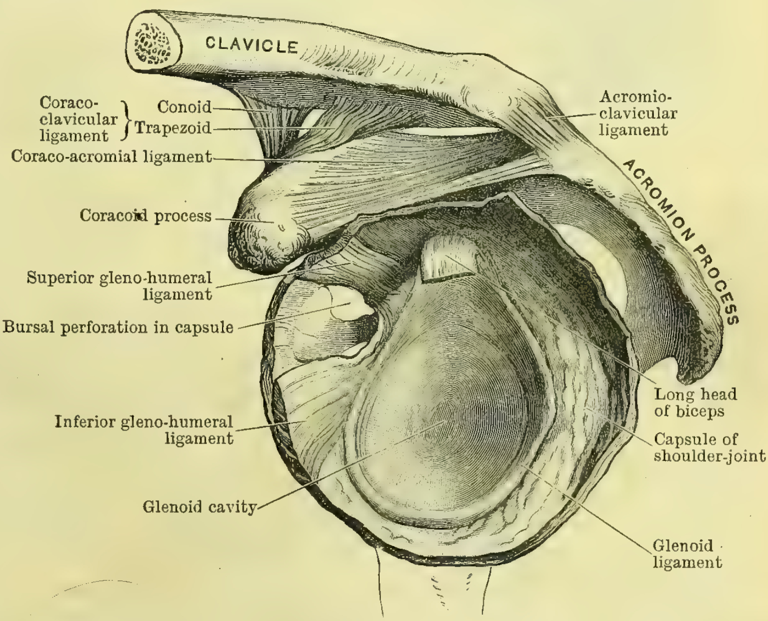


Fig. 209.—Capsular Ligament of Shoulder-joint cut across and Humerus removed.

Gleno-humeral Ligaments (Fig. 209).—If the capsule be opened from behind, and the head of the humerus be removed, it will be seen that the longitudinal fibres of the anterior part of the capsule are specially developed in the form of thick flattened bands which extend from the anterior border of the glenoid fossa to the anterior aspect of the neck of the humerus. These gleno-humeral

ligaments are three in number, and occupy the following positions: the **superior** is placed *above* the aperture in the front of the capsule; the **middle** and **inferior** on the antero-inferior aspect of the capsule, and *below* the aperture mentioned.

The superior gleno-humeral ligament, which some believe to represent the ligamentum teres of the hip-joint, springs, along with the middle gleno-humeral band, from the upper part of the anterior glenoid margin. The inferior band is the strongest of the three, and springs from the lower part of the anterior glenoid margin.

Intra-capsular Structures.—1. The glenoid ligament, already described. 2. The long tendon of the biceps passes outwards from its attachment to the apex of the glenoid fossa and the adjoining part of the glenoid ligament, above the head and neck of the humerus, to escape from the interior of the capsule by the opening between the tuberosities of the humerus, subjacent to the transverse humeral ligament.

Synovial membrane (Fig. 210) lines the capsule of the joint, and extends from the margin of the glenoid fossa to the humeral attachments of the capsule, where it is reflected towards the margin of the articular cartilage. It is therefore important to note that the inferior aspect of the humeral neck has the most extensive clothing of synovial membrane. Further, the synovial membrane envelops the intra-capsular part of the tendon of the biceps, and although this tubular sheath is prolonged upon the tendon into the upper part of the bicipital groove, yet the closed character of the synovial cavity is maintained. Thus, while the tendon is within the capsule, it is not within the synovial cavity. The synovial membrane is continuous with those bursæ which communicate with the joint cavity through openings in the ligamentous capsule.

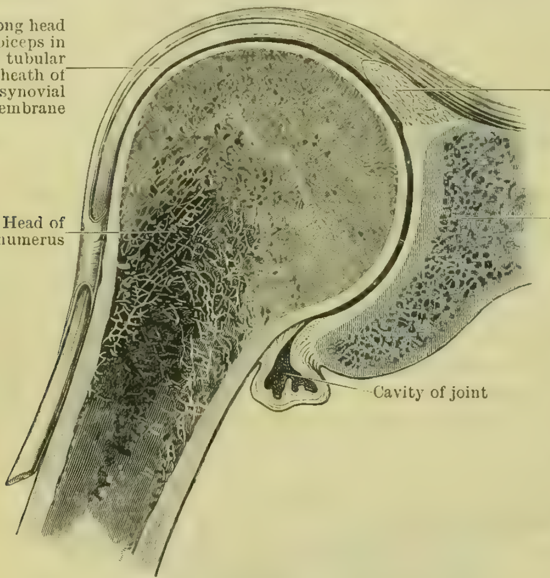


FIG. 210.—VERTICAL SECTION THROUGH THE SHOULDER-JOINT.

Bursæ (*a*) *Communicating with the Joint Cavity.*—Practically there is only one bursa which is constant in its position, viz. the **subscapular,** between the capsule and the tendon of the subscapularis muscle. It varies considerably in its dimensions, but its lining membrane is always continuous with that which lines the capsule (Figs. 207 and 208), and therefore it may be regarded merely as a prolongation of the articular synovial membrane. Occasionally a similar but smaller bursa occurs between the capsule and the tendon of the infraspinatus muscle.

(*b*) *Not communicating with the Joint Cavity.*—The **sub-deltoid** or **sub-acromial bursa** is situated between the muscles on the superior aspect of the shoulder-joint on the one hand and the deltoid muscle on the other. It is an extensive bursa, and is prolonged subjacent to the acromion process and the coraco-acromial ligament. It does not communicate with the shoulder-joint, but it greatly facilitates the movements of the upper end of the humerus against the under surface of the coraco-acromial arch.

Movements at the Shoulder-Joint.—A ball-and-socket joint permits of a great variety of movements, practically in all directions; but if these movements be analysed, it will be seen that they resolve themselves into movements about **three** primary axes at right angles to each other, or about axes which are the possible combinations of the primary ones.

Thus, about a transverse axis, the limb may move forwards **(flexion)** or backwards **(extension).** About an antero-posterior axis it may move outwards, *i.e.* away from the mesial plane of the trunk **(abduction),** or inwards, *i.e.* towards, and to some extent up to, the mesial plane **(adduction).**

About a vertical axis, the humerus may **rotate** upon its axis in an inward or outward direction to the extent of a quarter of a circle.

Since these axes all pass through the shoulder-joint, and since each may present varying degrees of obliquity, it follows that very elaborate combinations are possible until the movement of **circumduction** is evolved. In this movement the head of the humerus acts as the apex of a **cone of movement** with the distal end of the humerus, describing the base of the cone.

The range of the shoulder-joint movements is still further increased from the mobility of the scapula as a whole, and from its association with the movements of the clavicle already described.

THE ELBOW-JOINT.

This articulation (articulatio cubiti) provides an instance of a diarthrosis capable of performing the movements of flexion and extension about a single axis placed transversely, *i.e.* a typical ginglymus diarthrosis or hinge-joint.

The bones which enter into its formation are the humerus, ulna, and radius. The trochlea of the humerus articulates with the greater sigmoid cavity of the ulna (articulatio humero-ulnaris); the capitellum of the humerus articulates with the shallow depression or cup on the superior aspect of the head of the radius (articulatio humero-radialis). The articular cartilage clothing the trochlea of the humerus terminates in a sinuous or concave margin both anteriorly and posteriorly, so that it does not line either the coronoid or the olecranon fossa. Internally, it merely rounds off the inner margin of the trochlea, but externally it is continuous with the encrusting cartilage covering the capitellum, to the margin of which the cartilage extends in all directions, and thus it presents a convex edge in relation to the supra-capitellar or radial fossa. The cartilage which lines the greater sigmoid cavity of the ulna presents a transverse interruption, considerably wider on its inner as compared with its outer aspect. Thereby the coronoid and olecranon segments of the fossa are separated from each other. The cartilage which clothes the coronoid segment is continuous with that which clothes the lesser sigmoid cavity. The shallow cup-shaped depression on the head of the radius is covered by cartilage which rounds off the margin, and is prolonged without interruption upon the vertical aspect of the head, descending to its lowest level on that part opposed to the lesser sigmoid cavity.

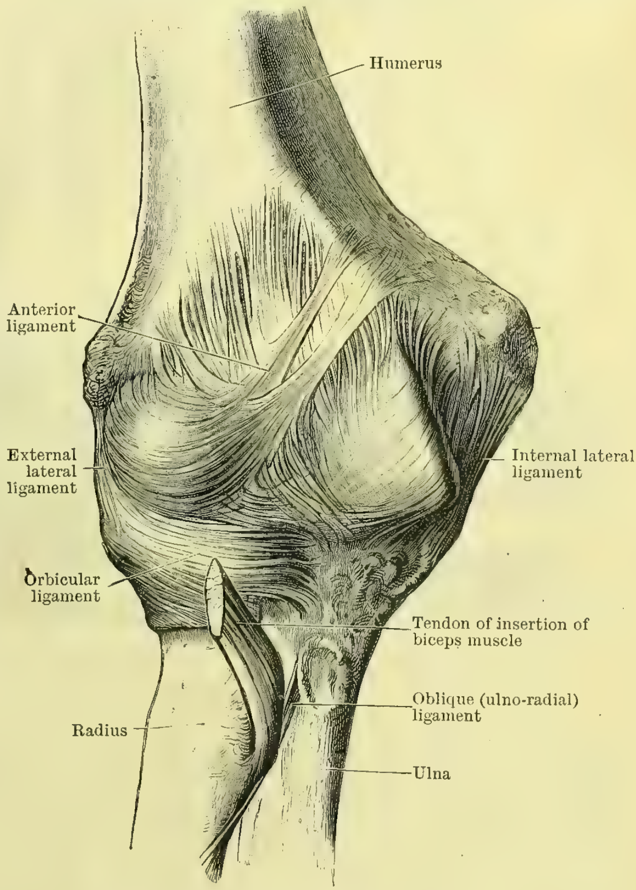


Fig. 211.—Anterior View of Elbow-joint.

Ligaments.—Taken as a whole, the ligaments form a complete **capsule** (capsula articularis), which is not defective at any point, although it is not of equal thickness throughout, and certain bands of fibres stand out distinctly because of their greater strength.

The **anterior ligament** (Fig. 211) consists of a layer whose fibres run in several

directions—obliquely, transversely, and vertically—and of these the vertical fibres are of most importance. It is attached above to the upper margins of the coronoid and supracapitellar fossæ; below, to the margins of the coronoid process and to the orbicular ligament of the superior radio-ulnar joint, but some loosely-arranged fibres reach as far as the neck of the radius. The lateral portions of this ligament, which are situated in front of the capitellum and inner margin of the trochlea respectively, are much thinner and weaker than the central part. Fibres of origin of the brachialis anticus muscle arise from the front of this ligament.

The **posterior ligament** is an extremely thin, almost redundant layer. Superiorly it is attached, in relation to the margin of the olecranon fossa, at a varying distance from the trochlear articular surface, and inferiorly to the summit and sides of the lip of the olecranon process. Externally some of its fibres pass from the posterior aspect of the capitellum to the posterior border of the lesser sigmoid cavity of the ulna. This ligament derives material support from, and participates in the movements of, the triceps muscle, since they are closely adherent to each other in the region of the olecranon process.

The **internal lateral ligament** (lig. collaterale ulnare, Figs. 211 and 212) is a fan-

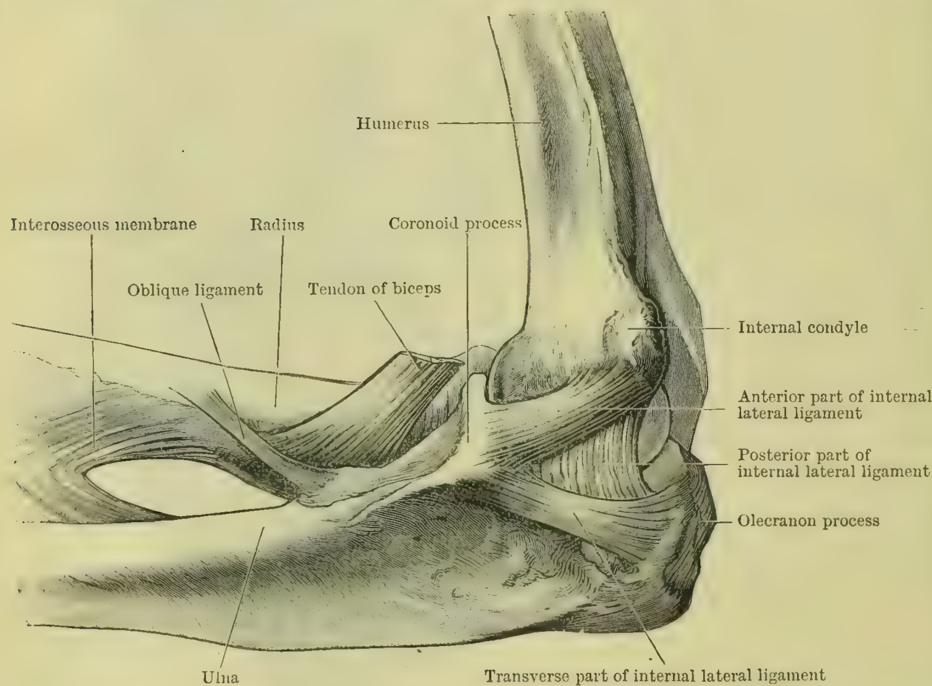


FIG. 212.—ELBOW-JOINT (inner aspect).

shaped structure of unequal thickness, but its margins, which are its strongest bands, are continuous with the adjoining parts of the anterior and posterior ligaments. By its upper end it is attached to the anterior, inferior, and posterior aspects of the internal condyle of the humerus. By its broad lower end it is attached to the inner margin of the greater sigmoid cavity, so that the *anterior band* is associated principally with the inner margin of the coronoid process, and the *posterior band* with the inner margin of the olecranon process, while the intermediate weaker portion sends its fibres downwards to join a *transverse band*, sometimes very strong, which bridges the notch between the adjoining inner margins of the coronoid and olecranon processes.

The **external lateral ligament** (lig. collaterale radiale, Fig. 211) is a strong flattened band attached superiorly to the lower and posterior aspects of the external condyle of the humerus. It completes the continuity of the capsule on the outer side, and blends inferiorly with the orbicular ligament, on the surface of which its fibres may be traced both to the anterior and posterior ends of the lesser sigmoid

notch. Both of the lateral ligaments are intimately associated with the muscles which take origin from the inner and outer condyles of the humerus.

Synovial Pads of Fat (Fig. 213).—Internal to the capsule, there are several pads of fat situated between it and the synovial membrane. Small pads are so placed as to lie immediately in front of the coronoid and supra-capitellar fossæ, but a larger one projects towards the olecranon fossa.

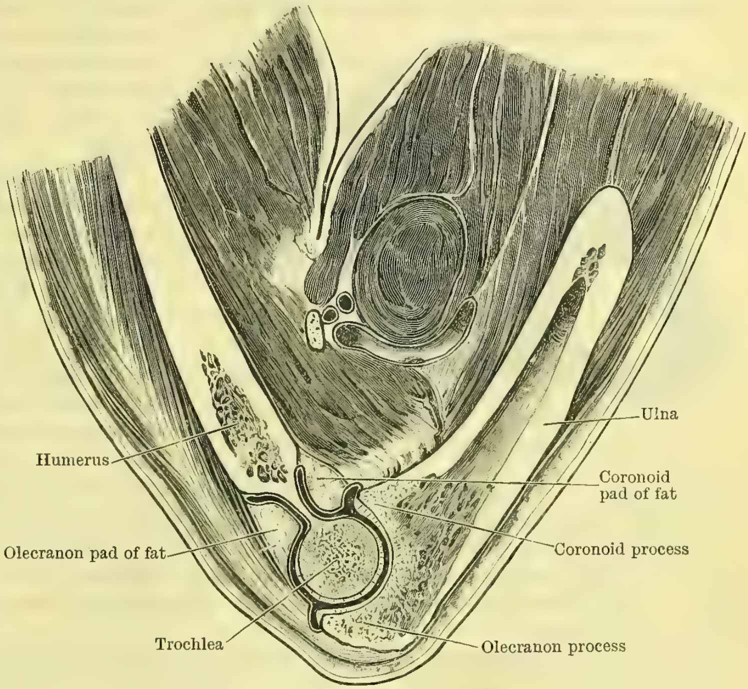


Fig. 213.—Vertical Section through the Trochlear Part of the Elbow-joint.

Synovial membrane (Fig. 213) lines the entire capsule and clothes the pads of fat above referred to, as well as those portions of bone enclosed within the capsule which are not covered by articular cartilage. By its disposition the elbow and the superior radio-ulnar joints possess a common joint cavity. It should be specially noted that the upper part of the neck of the radius is surrounded by this synovial membrane.

Movements at the Elbow-Joint.—The movements of the radius and ulna upon the humerus have already been referred to as those characterising a uniaxial joint constructed on the plan of a hinge. In this case the axis of the joint is obliquely transverse, so that in the extended position the humerus and ulna form an obtuse angle open towards the radius, whereas in the flexed position the hand is carried inwards in the direction of the mouth. Extreme flexion is checked by the soft parts in front of the arm and of the fore-arm coming into contact, and extreme extension by the restraining effect of the ligaments and muscles. In each case the movement is checked before either coronoid or olecranon processes come into contact with the humerus. The anterior and posterior bands of the internal lateral ligament are important factors in these results. Lateral movement of the ulna is not a characteristic movement, although it may occur to a slight extent, owing to a want of complete adaptation between the trochlear surface of the humerus and the sigmoid cavity of the ulna. This incongruence is noteworthy since the inner lip of the trochlea is prominent in front, and the outer lip is prominent behind. Consequently, this latter part is associated with a surface on the outer side of the olecranon which is only utilised in complete extension.

The capitellum and the opposing surface upon the head of the radius are always in varying degrees of contact. The head of the radius participates in the movements of flexion and extension, and is most closely and completely in contact with the humerus during the position of semi-flexion and semi-pronation. In complete extension a very considerable part of the capitellum is uncovered by the radius.

THE RADIO-ULNAR JOINTS.

These articulations, which are two in number, are situated at the proximal and distal ends of the radius and ulna. They provide an adaptation whereby the radius rotates around a longitudinal axis in the movements of pronation and supination, and hence this form of uniaxial diarthrosis is termed lateral ginglymus.

Superior Radio-ulnar Joint (articulatio radio-ulnaris proximalis).—In this joint the articular surfaces which enter into its formation are the lesser sigmoid cavity of the ulna and the lateral aspect of the head of the radius. In each case the articular cartilage is continuous with an articular surface entering into the

formation of the elbow-joint, consequently the joint cavity is continuous with that of the elbow-joint, and therefore, in a sense, it lies within the cover of the capsule of the elbow-joint; but its special feature is the—

Orbicular ligament (lig. annulare radii, Figs. 211 and 214), which has formerly been mentioned as the inferior line of attachment of the external lateral ligament and the ligaments on the front and back of the elbow-joint.

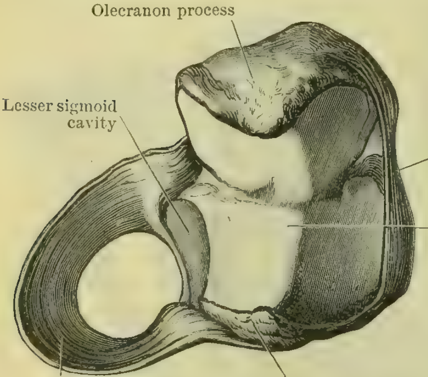


FIG. 214.—ORBICULAR LIGAMENT OF THE RADIUS.

It is a strong well-defined structure, attached by its extremities to the anterior and posterior margins of the lesser sigmoid cavity, and thus it forms nearly four-fifths of an osseo-tendinous circle or ring. This circle is somewhat wider at the upper than at the lower margin of the orbicular ligament, which, by encircling the upper part of the neck of the radius, tends to prevent displacement of the head of that bone in a downward direction. The lower margin of this ligament is not directly attached to the radius.

The **synovial membrane** is continuous with that which lines the elbow-joint. It closes the joint cavity at the inferior unattached margin of the orbicular ligament, where it is somewhat loosely arranged in its reflexion from the ligament to the neck of the radius.

Inferior Radio-ulnar Joint (articulatio radio-ulnaris distalis).—This joint is situated between the sigmoid cavity on the inner side of the lower end of the radius and the lateral aspect of the head of the ulna. In addition, it includes the inferior surface of the head of the ulna, which articulates with the superior surface of a triangular plate of fibro-cartilage, by means of which the joint is excluded from the radio-carpal articulation.

The **triangular interarticular fibro-cartilage** (discus articularis, Figs. 215 and 217), besides presenting articular surfaces to two separate joints, is an important ligament concerned in binding together the lower ends of the radius and ulna. It is attached by its apex to the depression at the outer side of the root of the styloid process of the ulna, and by its base to the sharp line of demarcation between the sigmoid cavity and the carpal articular surface of the radius.

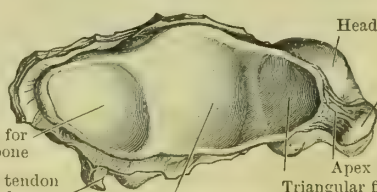


FIG. 215.—CARPAL ARTICULAR SURFACE OF THE RADIUS, AND TRIANGULAR FIBRO-CARTILAGE OF THE WRIST.

The **ligamentous capsule** is very imperfect, and consists of scattered fibres, termed the **anterior** and **posterior radio-ulnar** ligaments (Fig. 216). These ligaments pass transversely between adjoining non-articular surfaces on the radius and ulna, and are of sufficient length to permit of the movements of the radius.

The **synovial membrane** completes the closure of the joint cavity. It forms a loose bulging projection (recessus sacciformis), passing upwards between the lower ends of the shafts of the radius and ulna, and it also clothes the upper surface of the triangular fibro-cartilage (Fig. 217). The cavity of this joint is quite distinct from that of the radio-carpal articulation, except when the triangular fibro-cartilage presents a perforation.

Between the foregoing articulations there are two **accessory ligaments**, viz. the interosseous membrane and the oblique ligament, which connect together the shafts of the radius and ulna.

The **interosseous membrane** (Fig. 212) of the forearm (membrana interossea interbrachii) is a strong fibrous membrane which stretches across the interval between the radius and ulna, and is firmly attached to the interosseous border of each. Below it extends downwards to the lower limit of the space between the bones, whilst above it does not reach higher than a point about one inch below the tuberosity of the radius. A gap, called the *hiatus interosseus,* is thus left above its upper margin, and through this the posterior interosseous artery passes backwards between the bones to reach the dorsal aspect of the forearm. This gap is bounded above by the oblique ligament. The fibres which compose the interosseous membrane run for the most part downwards and inwards from the radius to the ulna, although on its dorsal aspect several bands may be observed stretching in an opposite direction. The interosseous membrane augments the surface for the origin of the muscles of the forearm; it braces the radius and ulna together; and when shocks are communicated from the hand to the radius, owing to the direction of its fibres, the interosseous membrane transmits these, to some slight extent, to the ulna.

The **oblique ligament** (Fig. 212) is a slender tendinous band of very varying strength which springs from the outer part of the coronoid process of the ulna, and stretches obliquely downwards and outwards to the radius where it is attached immediately below the bicipital tuberosity.

Movements of the Radius on the Ulna.—The axis about which the radius moves is a longitudinal one, having one end passing through the centre of the head of the radius and the other through the styloid process of the ulna and the line of the ring-finger. In this axis the head of the radius is so secured that it can only rotate upon the lesser sigmoid cavity of the ulna within the orbicular ligament, and consequently the radial head remains upon the same plane as the ulna; but the lower end of the radius being merely restrained by the triangular fibro-cartilage, is able to describe nearly a half-circle, of which the apex of this ligament is the centre. In this movement the radius carries the hand from a position in which the palm is directed forwards, and in which the radius and ulna lie parallel to each other (**supination**), to one in which the palm is directed backwards, and the radius lies diagonally across the front of the ulna (**pronation**).

The ulna is unable to rotate upon a long axis, but while the radius is travelling through the arc of a circle from without inwards in front of the ulna, it will usually be seen that the ulna appears to move through the arc of a smaller circle in the reverse direction, viz. from within outwards. If the humerus be prevented from moving at the shoulder-joint, a very large proportion, if not the entire amount ~~, of~~ this apparent movement of the ulna will disappear. At the same time some observers maintain that it really occurs at the elbow-joint, associated with lateral movement during slight degrees of flexion and extension at that joint.

THE RADIO-CARPAL JOINT.

This joint (articulatio radiocarpea) is a bi-axial diarthrosis, frequently called a condyloid joint.

The articular elements which enter into its formation are: on its *proximal side,* the inferior surface of the lower end of the radius, together with the inferior surface of the triangular fibro-cartilage; on its *distal side,* the superior articular surfaces of the scaphoid, semilunar, and cuneiform bones. The articular surface of the radius is concave both in its antero-posterior and transverse diameters, in order to adapt itself to the opposing surfaces of the scaphoid and semilunar, which are convex in the two axes named. In the ordinary straight position of the hand the triangular fibro-cartilage is in contact with the semilunar bone, and the upper articular surface of the cuneiform bone is in contact with the capsule of the joint. When, however, the hand is bent towards the ulna, the cuneiform bone is carried outwards as well as the semilunar and scaphoid, and the triangular fibro-cartilage comes into contact with the cuneiform. The articular surface of the radius is subdivided by an antero-posterior, slightly elevated ridge, into an outer triangular facet which usually articulates with the scaphoid, and an inner quadrilateral facet for articulation with a portion of the semilunar bone.

In the intervals between the scaphoid, semilunar, and cuneiform bones, the continuity of the articular surfaces is usually maintained by the presence of interosseous ligaments which are situated upon the same level as the articular cartilage.

Ligaments.—A capsular ligament completely surrounds the joint. It is somewhat loosely arranged, and permits of subdivision into the following portions:—

The **external lateral ligament** (Fig. 216) is a well-defined band which is attached

by one end to the tip of the styloid process of the radius, and by the other to a rough area at the base of the tubercle of the scaphoid bone, *i.e.* external to its radial articular surface.

The **internal lateral ligament** (Fig. 216) is also a distinct rounded structure, having one end attached to the tip of the styloid process of the ulna and the other to the rough non-articular border of the cuneiform bone, some of its fibres being prolonged to the pisiform bone.

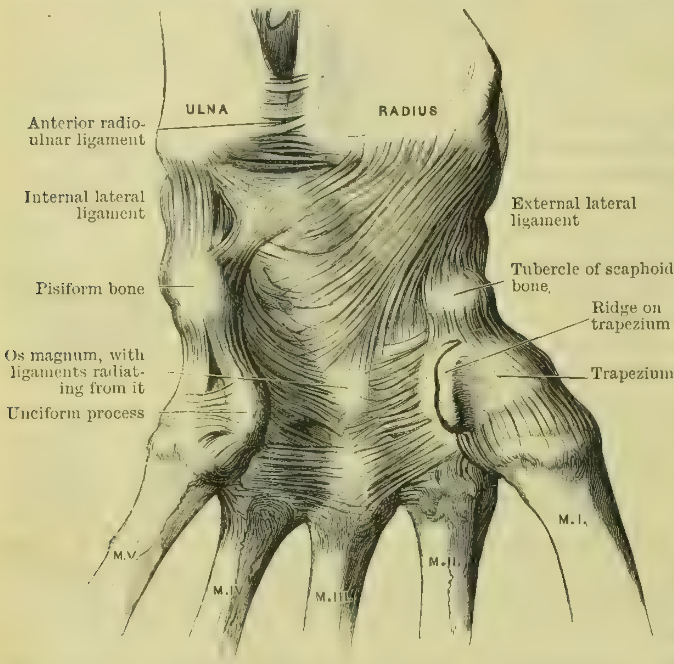


FIG. 216.—LIGAMENTS ON ANTERIOR ASPECT OF RADIO-CARPAL, CARPAL, AND CARPO-METACARPAL JOINTS.

The **anterior ligament** (Fig. 216) is attached superiorly to the anterior margin of the lower end of the radius, as well as slightly to the base of the styloid process of the ulna. Some transverse fibres may be seen, but the greater number pass obliquely downwards and inwards to the palmar non-articular surfaces of the scaphoid, semilunar, and cuneiform bones, while some of them may even be continued as far as the os magnum. Those fibres from the ulna run obliquely outwards. On its deeper aspect this ligament is closely adherent to the anterior border of the triangular fibro-cartilage of the inferior radio-ulnar articulation.

The **posterior ligament** extends from the posterior margin of the lower end of the radius, obliquely downwards and inwards, to the dorsal non-articular areas on the proximal row of the carpal bones. The slip to the latter assists in forming the fibrous sheath through which the tendon of the extensor carpi ulnaris muscle travels to its insertion. The principal bundle of fibres is connected with the cuneiform bone.

The **synovial membrane** (Fig. 217) is simple, and is confined to the articulation, except in those cases in which the triangular fibro-cartilage is perforated, or in which one of the interosseous ligaments between the carpal bones of the first row is absent.

Movements at the Radio-carpal Joint.—The radio-carpal joint affords an excellent example of a biaxial articulation, in which a long transverse axis of movement is situated more or less at right angles to a short axis placed in the antero-posterior direction. The nature of the movements which are possible about these two axes is essentially the same in both cases, viz. **flexion** and **extension.** The movements about the longer transverse axis are anterior or palmar flexion, extension, and its continuation into dorsi-flexion. About the shorter antero-posterior axis we get movements which result from combined action by certain flexor and extensor muscles, whereby the radial or ulnar borders of the hand may be approximated towards the corresponding borders of the forearm. Lateral movement may also be possible to a slight extent. The range of movement in connexion with either of the principal axes is largely a matter of individual peculiarity, for, with the exception of the lateral ligaments, there is no serious obstacle to the cultivation of greater mobility at the radio-carpal joint.

CARPAL JOINTS.

The articulations subsisting between the individual carpal bones (articulationes intercarpeæ) are all diarthroses, and although the total amount of movement throughout the series is considerable, yet the extent of movement which is possible

between the two rows or between any two carpal bones is extremely limited. For this reason, as well as because of the nature of the movement, these articulations are called gliding joints (arthrodia).

It is advisable to consider, *first*, the articulations between individual bones of the proximal row; *second*, the articulations between the separate bones of the distal row; *third*, the articulation of the proximal and distal rows with each other; *fourth*, the pisiform articulation.

The **proximal row of carpal articulations** (Fig. 216) comprises the joints between the scaphoid, semilunar, and cuneiform bones. On their adjacent lateral aspects these bones are partly articular and partly non-articular.

Three sets of simple but strong, although short ligamentous bands bind these three carpal bones together, and form an investment for three sides of their intercarpal joints. These are—(1) the **anterior** or **palmar ligaments**, two in number, which consist of transverse fibres passing between the adjacent rough palmar surfaces of the bones; (2) the **posterior** or **dorsal ligaments**, also two in number, and composed of similar short transverse fibres passing between the adjacent dorsal surfaces; (3) the **interosseous ligaments** (Fig. 217), again two in number, and transverse in direction, situated on a level with the superior articular surfaces, and extending from the palmar to the dorsal aspect of the bones, while attached to non-articular areas of the opposing surfaces. The radio-carpal joint is entirely shut off from the intercarpal joints, and also from the joint between the two rows of carpal bones, except in rare cases, when an interosseous ligament is wanting.

The **distal row of carpal articulations** (Fig. 216) includes the joints between the trapezium, trapezoid, os magnum, and unciform bones. Articular facets occur on the opposing lateral faces of the individual bones.

Associated with this row there are again simple bands of considerable strength, and presenting an arrangement similar to that seen in the proximal row. As in the former case, they invest the intercarpal articulations, except on the superior aspect, where they communicate with the transverse carpal joint, and on the inferior aspect, where they communicate with the carpo-metacarpal joint cavity.

The **anterior** or **palmar ligaments** are three in number. They extend in a transverse direction between contiguous portions of the rough palmar surfaces of the bones. The **posterior** or **dorsal ligaments**, also three in number, are similarly disposed on the dorsal aspect. The **interosseous ligaments** (Fig. 217) are two or three in number. That which joins os magnum to unciform is the strongest; that between the trapezoid and os magnum is situated towards the dorsal parts of their opposing surfaces; the third, situated between contiguous non-articular surfaces of the trapezium and trapezoid, is always the feeblest, and is frequently absent.

The **transverse carpal articulation** (Fig. 217) is situated between the proximal and distal rows of the carpus. The bones of the proximal row present the following characters on their inferior or distal aspect. The outer part of the articular surface is deeply concave, both in the antero-posterior and in the transverse directions, but the inner part of the same surface is concavo-convex, more especially in the transverse direction.

Superiorly, the articular surfaces of the distal row of carpal bones present an irregular outline. That part pertaining to the trapezium and trapezoid is concave in the antero-posterior and transverse directions, and lies at a considerably lower level than the portion belonging to the os magnum and unciform, which is, moreover, markedly convex in the antero-posterior and transverse directions, with the exception of the innermost part of the unciform, where it is concavo-convex in both of these directions.

This articulation is invested by a complete short **capsule** (Fig. 216) which binds the two rows of the carpus together, and sends prolongations to the investing capsules of the proximal and distal articulations. The ligament as a whole is very strong, and individual bands are not readily defined, although certain special bands may be described. The **palmar ligaments** radiate from the os magnum to the scaphoid, cuneiform, and pisiform. The interval between the os magnum and semilunar is occupied by oblique fibres, some of which pass from scaphoid to cuneiform, while these are joined by others, prolonged obliquely downwards and inwards, from the

radial end of the anterior radio-carpal ligament. By these different bands the palmar aspect of the joint is completely closed.

The **dorsal ligaments** are more feeble than the palmar. They form a thin, loosely-arranged stratum, in which the only noteworthy bands are one which joins the scaphoid to os magnum, and another which joins cuneiform to unciform.

The **external lateral ligament** (lig. collaterale carpi radiale, Fig. 217) extends between contiguous rough areas on the radial aspects of the scaphoid and trapezium. By its margins it is continuous both with the palmar and dorsal ligaments.

The **internal lateral ligament** (lig. collaterale carpi ulnare, Fig. 217) is arranged like the former in regard to its margins, and by its ends it is attached to the contiguous rough ulnar surfaces of the cuneiform and unciform bones.

Both of these lateral ligaments are directly continuous with the corresponding lateral ligaments of the radio-carpal joint.

An **interosseous ligament** (Fig. 217) is occasionally found within the capsule, extending across the joint cavity between the os magnum and the scaphoid.

The **pisi-cuneiform articulation** is an arthrodial diarthrosis. The mutual articular surfaces of the two bones are flattened and circular, and only permit of a small amount of gliding movement.

The joint is provided with a thin but complete **capsule** of fibrous tissue, which is specially strengthened inferiorly by two strong bands, viz. **pisi-unciform** (lig. pisohamatum) and **pisi-metacarpal** (lig. pisometacarpeum, Fig. 216). Both of these bands extend from the lower and inner aspect of the pisiform to adjoining parts of the hook of the unciform and base of the fifth metacarpal bone respectively. To a great extent these ligamentous bands may be regarded as extensions of the insertion of the tendon of the flexor carpi ulnaris muscle which is attached to the upper part of the pisiform bone. Looked at as ligaments, however, they are specially strong to prevent the displacement of the pisiform bone during contraction of the muscle inserted into it.

The **synovial membranes** (Fig. 217) of the carpal joints are two in number. Of these, one is restricted to the pisicuneiform articulation, and is correspondingly simple, although occasionally the joint cavity may communicate with that of the radio-carpal joint.

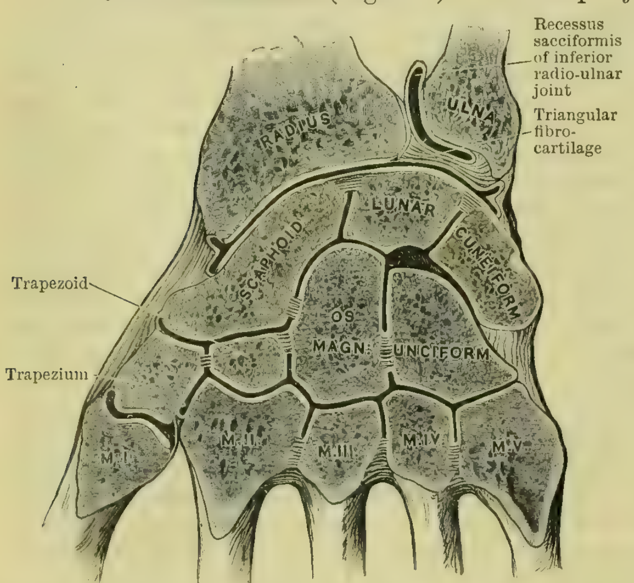


FIG. 217.—CORONAL SECTION through the radio-carpal, carpal, carpo-metacarpal, and intermetacarpal joints, to show joint cavities and interosseous ligaments (diagrammatic).

The other synovial membrane is associated with the transverse carpal joint which extends transversely between the two rows of carpal bones, with prolongations into the vertical intervals between the adjoining bones of each row, *i.e.* the intercarpal articulations. It is, therefore, an elaborate cavity, which may be still further extended, by the absence of interosseous ligaments, so as to reach the radio-carpal and carpo-metacarpal series of joints. The first condition is rare, but the second is not uncommon, and results from the absence of the interosseous ligament between trapezium and trapezoid, or of that between trapezoid and os magnum.

INTERMETACARPAL JOINTS.

The four inner metacarpal bones articulate with each other at their proximal ends or bases, between the opposing surfaces of which joint cavities are found—arthrodial diarthroses. These cavities are continuous with the carpo-metacarpal joint (not yet described), and hence the ligamentous arrangements only enclose three aspects of each joint.

Three strong **transverse ligaments** (Figs. 216 and 217) bind adjacent palmar, dorsal, and interosseous areas of the bases of the metacarpal bones, and hence they are called **ligamenta basium** (oss. metacarp.) **volaria, dorsalia et interossea.** A synovial membrane is associated with each of these joints, but it may be regarded as a prolongation from the carpo-metacarpal articulation.

CARPO-METACARPAL JOINTS.

The articulation of the metacarpal bone of the thumb with the trapezium differs in so many respects from the articulation between the other metacarpal bones and the carpus, that it must be considered separately.

(*A*) The **articulatio carpo-metacarpea pollicis** (Figs. 216 and 217) is the joint between the infero-external surface of the trapezium and the superior surface of the base of the first metacarpal bone. Both of these surfaces are saddle-shaped, and they articulate by mutual co-aptation.

The joint-cavity is surrounded by a fibrous **capsule**, in which we may recognise palmar, dorsal, external, and internal lateral bands, the last being the strongest and most important.

Synovial membrane lines the capsule, and the joint-cavity is isolated and quite separate from the other carpal and carpo-metacarpal articulations.

At this joint movements occur about at least three axes. Thus, around a more or less transverse axis, **flexion** and **extension** take place ; in an antero-posterior axis **abduction** and **adduction** (movements which have reference to the middle line of the hand) are found ; while a certain amount of **rotation** is possible in the longitudinal axis of the digit. The very characteristic movement of **opposition**, in which the tip of the thumb may be applied to the tips of all the fingers, results from a combination of flexion, adduction, and rotation, and by combining all the movements possible at the various axes, a considerable degree of **circumduction** may be produced, in spite of the fact that this is not a ball-and-socket joint.

(*B*) The **articulationes carpo-metacarpeæ digitorum** are the joints between the bases of the four inner metacarpal bones and the four bones of the distal row of the carpus. They are all arthrodial diarthroses, and the opposed articular surfaces present alternate elevations and depressions which form a series of interlocking joints. The joint-cavities between the carpal bones of the distal row, and also the more extensive intermetacarpal joint cavities, open into this articulation.

This series of joints is invested by a common capsule which is weakest on its radial side, but is otherwise well defined. Its fibres arrange themselves in small slips, which pass obliquely in different directions, and vary in number for each metacarpal bone. Thus the **oblique palmar ligaments** (ligamenta carpo-metacarpea volaria, Fig. 215) usually consist of one slip for each metacarpal bone, but there may be two slips, and the third metacarpal bone frequently has three, of which one lies obliquely in front of the tendon of the flexor carpi radialis muscle.

The **oblique dorsal ligaments** (ligamenta carpo-metacarpea dorsalia) are similar short bands, of greater strength and clearer definition, by which the index metacarpal is bound to the trapezium and trapezoid ; the middle metacarpal to the os magnum, and frequently to the trapezoid; the ring metacarpal to the os magnum and unciform, and the metacarpal of the minimus to the unciform.

Interosseous ligaments, one or sometimes two in number, occur within the capsule. They are usually situated in relation to one or both of the contiguous margins of the bases of the third and fourth metacarpal bones, from which they extend upwards to adjacent margins of the os magnum and unciform. Occasionally they are sufficiently developed to divide the joint cavity into radial and ulnar sections.

The **synovial membrane** (Fig. 217) is usually single and lines the capsule, but, as already explained, it has prolongations into the intermetacarpal and intercarpal series of joints. In connexion with the latter, the frequent absence of the interosseous ligament between the trapezium and trapezoid permits the free communication of this joint-cavity with that of the transverse carpal joint.

METACARPO-PHALANGEAL JOINTS.

In the case of the pollex this joint is constructed on the plan of a ginglymus diarthrosis; the four corresponding joints of the fingers are also diarthroses of a slightly modified ball-and-socket variety. With the exception of the metacarpal bone of the pollex, each metacarpal bone has a somewhat spherical head articulating with a shallow oval cup upon the base of the first phalanx. The articulation in the thumb presents features similar to those of an interphalangeal joint.

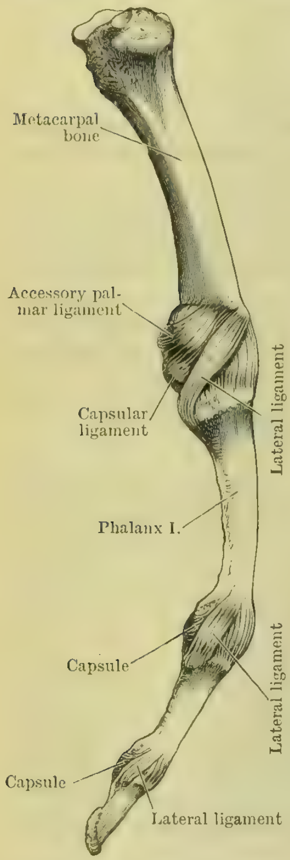


FIG. 218.—METACARPO-PHALANGEAL AND INTERPHALANGEAL JOINTS.

Each joint possesses an articular capsule (Fig. 218) which presents very different degrees of strength in different aspects of the articulation. Thus, on the dorsal aspect, it cannot be demonstrated as an independent structure, but the necessity for dorsal ligaments is to a large extent obviated by the presence of the strong flattened expansions of the extensor tendons.

The **internal** and **external lateral ligaments** (ligamenta collateralia, Fig. 218) are strong cord-like bands which pass from the tubercles and adjacent depressions on the sides of the heads of the metacarpal bones to the contiguous non-articular areas on the bases of the proximal phalanges. They are intimately connected on their anterior aspects with the palmar ligaments.

The **palmar ligaments** consist of thick plates of fibro-cartilage loosely connected to the metacarpal bones, but firmly adherent to the phalanges. They are placed between the lateral ligaments, to both of which they are in each case connected. Each plate is grooved on the palmar surface for the long flexor tendons, whilst on its reverse or joint surface it supports and glides upon the head of the metacarpal bone during flexion and extension of the joint. In the case of the thumb this plate of fibro-cartilage usually develops two sesamoid bones, and in the case of the index finger one such sesamoid nodule is frequently found at the radial side of the plate.

An important accessory ligament is found in connexion with the four inner metacarpo-phalangeal articulations, viz.:—

The **Transverse Metacarpal Ligament.**—This structure binds together the distal extremities of the four inner metacarpal bones. The name is applied to three sets of transverse fibres of great strength which are situated in front of the three inner interosseous spaces. These fibres are continuous with the palmar metacarpo-phalangeal ligaments at their lateral margins.

A **synovial membrane** lines the investing capsule of each joint.

INTERPHALANGEAL JOINTS.

Of these joints there are two for each finger and one for the thumb. They all correspond, in being ginglymus diarthroses in which the trochlear character of their articular surfaces is associated with one axis of movement directed transversely.

In their general arrangement they correspond with each other, and to a large extent with the metacarpo-phalangeal series already described. Each is provided

with a definite **capsule** (Fig. 218), of which the palmar and cord-like lateral portions are well marked, while on the dorsal aspect the extensor tendons act as the chief support. The palmar ligaments are fibrous plates of considerable thickness, and are attached to the two lateral ligaments and to the intervening rough surface on the distal phalanges, while their proximal margins are not attached to bone. Each ligament has its lateral margins prolonged proximally to the adjacent sharply-defined lateral ridges on the phalangeal shafts.

The **lateral ligaments** (Fig. 218) are strong, rounded, short bands, continuous with the preceding, and attached to adjacent non-articular lateral aspects of the phalanges.

Each joint possesses a **synovial membrane** which lines its capsule, but its arrangement presents no special peculiarity.

Movements of the Carpal, Intermetacarpal, Metacarpo-phalangeal and Interphalangeal Joints.

The amount of movement which is possible at individual joints of the intercarpal, intermetacarpal, and carpo-metacarpal series is extremely limited, both on account of the interlocking nature of the articular surfaces and the restraining character of the ligamentous bands. Taken as a whole, however, the movements of the carpus and metacarpus enable the hand to perform many varied and important functions. This is largely due to the greater mobility of those joints on the radial and ulnar borders of the hand, as well as to the general elasticity of the arches formed by the carpus and metacarpus. These conditions particularly favour the movements of opposition and prehension. In the opposite direction, *i.e.* when pressure is applied from the palmar aspect, the metacarpal and carpal arches tend to become flattened, but great elasticity is imparted by the tension of the various ligaments.

The four inner metacarpo-phalangeal joints are ball-and-socket joints, and movements of **palmar-flexion** and **extension** are freely performed about a transverse axis. In exceptional cases a certain amount of **dorsi-flexion** is possible. About an antero-posterior axis movements occur which are usually referred to the middle line of the hand, and hence called **abduction** and **adduction.**

The movements of the index finger are less hampered than in the case of the others, but each of them can perform a modified kind of **circumduction.**

The metacarpo-phalangeal joint of the thumb and all the interphalangeal joints are uniaxial or hinge-joints acting about a transverse axis, which permits of **palmar-flexion** and **extension** being freely performed, but **dorsi-flexion** is, as a rule, entirely prevented by the palmar and lateral ligaments.

ARTICULATIONS AND LIGAMENTS OF THE PELVIS.

Although we may consider the pelvis as a separate part of the skeleton, yet it is essential to remember that the bones which enter into its composition belong to the spinal column (sacrum, coccyx) and the lower limb (innominate bone). Accordingly, the articulations, with their corresponding ligaments, may be arranged as follows:—

(*a*) Those by which the segments of the coccyx are joined together (already described, *v.* p. 256);

(*b*) That by which the sacrum articulates with the coccyx (already described, *v.* p. 256);

(*c*) Those by which the sacrum articulates with the last lumbar vertebra (Lumbo-sacral joints);

(*d*) Those by which the innominate bones are attached to the spinal column (Sacro-iliac joints);

(*e*) That by which the innominate bones are attached to each other (Symphysis pubis).

LUMBO-SACRAL JOINTS.

The articulation of sacrum with the fifth lumbar vertebra is constructed precisely on the principle of the articulations between two typical vertebræ, and the usual ligaments associated with such joints are repeated. There is, however, an additional accessory ligament, termed the **lateral lumbo-sacral ligament** (Fig. 219). This extends from the front of the inferior border of the transverse process of the

last lumbar vertebra, downwards and slightly outwards, to the front of the lateral aspect of the ala of the sacrum, close to the sacro-iliac joint. Further, a variable membranous band extends between the lateral aspect of the lower part of the body of the last lumbar vertebra and the front of the ala of the sacrum. This band lies in front of the anterior primary division of the fifth lumbar nerve.

SACRO-ILIAC JOINT.

Each innominate bone articulates with the sacral section of the spinal column on each side through the intervention of a diarthrosis, termed the **sacro-iliac joint** (articulatio sacroiliaca).

This joint is formed between the contiguous auricular surfaces of the sacrum and ilium. Each of these surfaces is more or less completely clothed by hyaline articular cartilage. The joint-cavity, which is little more than a capillary interval, may be crossed by fibrous bands.

The joint-cavity is surrounded by ligaments of varying thickness and strength, which constitute its **capsule**. Thus the anterior part of the investing capsule is thin, and consists of short but strong fibres which pass between adjoining surfaces on the ala of the sacrum and the iliac fossa of the innominate bone; they form the **anterior sacro-iliac ligament** (lig. sacro-iliacum anterius, Fig. 219). On the posterior aspect there are two ligaments. The **short posterior sacro-iliac ligament** (lig. sacro-iliacum posterius breve, Fig. 220) consists of numerous strong fasciculi, which pass from the rough area on the inner aspect of the ilium, above and behind its auricular surface, downwards and inwards to the transverse tubercles and the depressions behind the first and second segments of the sacrum. This ligament is of great strength, and with its fellow it is responsible for suspending the sacrum and the weight of the superimposed trunk from the innominate bones.

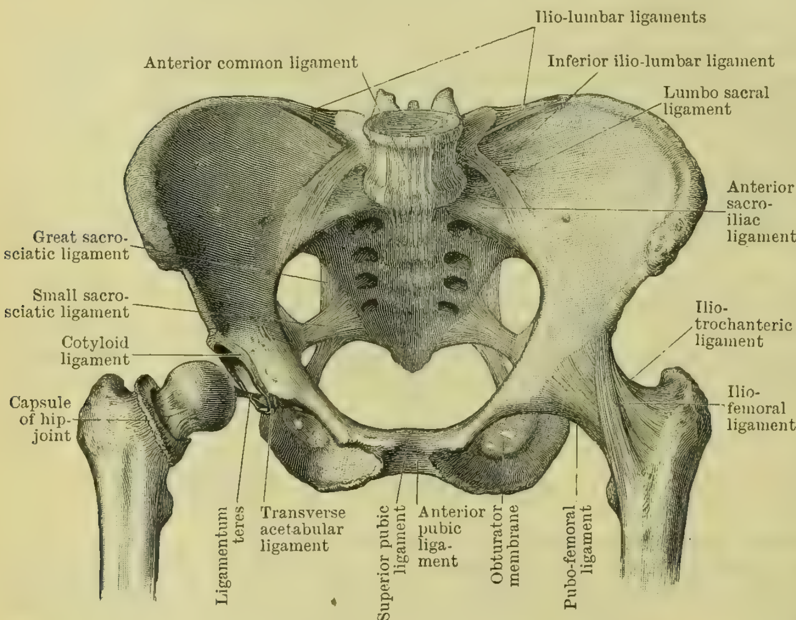


FIG. 219.—PELVIC JOINTS AS SEEN FROM THE FRONT.

The **long or oblique posterior sacro-iliac ligament** (lig. sacro-iliacum posterius longum, Fig. 220) is a superficial thickened portion of the preceding ligament. It consists of a definite band of fibres passing from the postero-superior iliac spine to the transverse tubercles of the third and fourth segments of the sacrum.

The **synovial cavity** of this joint is very imperfect and rudimentary.

Several accessory ligaments are associated with the articulation of the innominate bone to the sacral section of the spinal column.

The **ilio-lumbar ligament** (lig. ilio-lumbale, Fig. 219), which is merely the thickened anterior lamina of the fascia lumborum, extends from the tip of the transverse process of the last lumbar vertebra, almost horizontally outwards, to the inner lip of the iliac crest at a point a short distance behind its highest level.

A proportion of these fibres is attached to the inner rough surface of the ilium between the iliac crest and the auricular impression. To these the name of the **lig. ilio-lumbale inferius** is applied (Fig. 219).

The **great** or **posterior sacro-sciatic ligament** (lig. sacro-tuberosum, Fig. 220) is somewhat triangular in outline. It occupies the interval between the sacrum and the innominate bone, and is attached mesially, to the posterior inferior spine of the ilium; to the posterior aspect of the transverse tubercles and lateral margins of the third, fourth, and fifth segments of the sacrum, as well as to the side of the first segment of the coccyx. It passes downwards and outwards, becoming narrower as it approaches the ischium, near to which, however, it again expands, to be attached to the inner side of the ischial tuberosity, immediately below the groove for the tendon of the obturator internus muscle, *i.e.* the lesser sciatic notch. A continuation of the inner border of the ligament—the **processus falciformis** (Fig. 220)—runs upwards and forwards on the inner aspect of the ramus of the ischium.

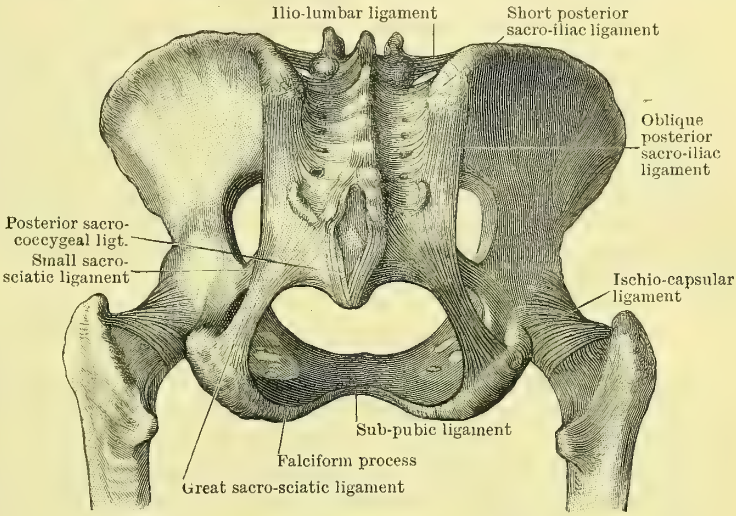


FIG. 220.—PELVIC LIGAMENTS AS SEEN FROM BEHIND.

The great sacro-sciatic ligament is believed by many to represent the original or proximal end of the long or ischial head of the biceps flexor cruris muscle.

The **small** or **anterior sacro-sciatic ligament** (lig. sacro-spinosum, Figs. 219 and 220) is situated in front, and in a measure under cover of the great sacro-sciatic ligament. Triangular in form, it is attached by its base to the last two segments of the sacrum and the first segment of the coccyx, and by its pointed apex to the tip and upper aspect of the ischial spine. This ligament is intimately associated with the coccygeus muscle, and by some it is regarded as being derived from it by fibrous transformation of the muscle fasciculi.

By the great and small sacro-sciatic ligaments the two sciatic notches of the innominate bone are converted into foramina. Thus the small sacro-sciatic ligament completes the boundaries of the great sciatic foramen (foramen ischiadicum majus); while the great sacro-sciatic ligament, assisted by the small sacro-sciatic ligament, closes the small sciatic foramen (foramen ischiadicum minus).

SYMPHYSIS PUBIS.

The anterior wall of the osseous pelvis is completed by the articulation of the bodies of the two pubic bones constituting the **symphysis pubis**. This joint conforms in its construction to the general plan of an amphiarthrosis. Thus it is mesial in position; each pubic bone is covered by a layer of hyaline cartilage, which closely adapts itself to the rough tuberculated surface of the pubic bone; while between these two hyaline plates there is an interposed fibro-cartilage (lamina fibro-cartilaginea interpubica), in the interior of which there is usually a vertical antero-posterior cleft. This cavity, which is placed nearer the posterior than the anterior aspect of the joint, does not appear until between the seventh and tenth years, and as it is not lined by a synovial membrane, it is supposed to result from the breaking down of the interpubic lamina.

The **anterior pubic ligament** (lig. pubicum anterius, Fig. 219) is a structure of considerable thickness and strength. Its superficial fibres, which are derived very largely from the tendons and aponeuroses of adjoining muscles, are oblique, and form an interlaced decussation. The deeper fibres are short, and extend transversely from one pubic bone to the other.

The **posterior pubic ligament** (lig. pubicum posterius, Fig. 220) is very weak, and consists of scattered fibres which extend transversely between contiguous pubic surfaces posterior to the articulation.

The **superior pubic ligament** (lig. pubicum superius, Fig. 219) is likewise weak, and consists of transverse fibres passing between the two pubic crests.

The **inferior** or **subpubic ligament** (lig. pubicum inferius vel lig. arcuatum pubis, Fig. 220) occupies the arch of the pubis, and is of considerable strength. It gives roundness to the pubic arch and forms part of the pelvic outlet. It has considerable vertical thickness immediately below the interpubic disc to which it is attached. Laterally it is attached to adjacent sides of the descending rami of the pubis. Its lower border is free, and separated from the triangular ligament of the perineum by a transverse oval interval through which the dorsal vein of the penis passes backwards to the interior of the pelvis.

The Triangular Ligament of the Perineum.

The **triangular ligament of the perineum** is a membranous structure which occupies the pubic arch below, and is distinct from the subpubic ligament. It assists in completing the pelvic walls anteriorly in the same manner that the obturator membrane does laterally. Indeed, these two structures occupy the same morphological plane. The triangular ligament presents two surfaces—one superficial or perineal; the other deep, or pelvic, and both of these surfaces are associated with muscles. Its lateral borders are attached to the sides of the pubic arch, while its base is somewhat ill-defined, by reason of its fusion with the fascia of Colles in the urethral region of the perineum.

The apex of the triangular ligament is truncated, free, and well-defined, constituting the **transverse perineal ligament**, above which there is the interval for the dorsal vein of the penis. It is pierced by a number of vessels and nerves, but the principal opening is situated mesially one inch below the pubic arch, and transmits the urethra.

The Obturator Membrane.

The **obturator membrane** (membrana obturatoria, Fig. 219) occupies the obturator or thyroid foramen. It is attached to the pelvic aspect of the circumference of this foramen. It consists of fibres irregularly arranged and of varying strength, so that sometimes it almost appears fenestrated. At the highest part of the foramen it is incomplete and forms a U-shaped border, between which and the bony circumference of the foramen, the obturator canal (canalis obturatorius) is formed. In this position the membrane is continuous with the parietal pelvic fascia which clothes the inner side of the obturator internus muscle, above the upper free margin of the muscle. From the outer or crural aspect of the membrane some of its fibres are prolonged to the antero-inferior aspect of the capsule of the hip-joint.

Mechanism and Movements of the Pelvis.—The human pelvis presents a mechanism the principal requirement of which is stability and not movement, for, through the pelvis, the weight of the trunk, superimposed upon the sacrum, is transmitted to the lower limbs. Moreover, its stability is largely concerned in the maintenance of the erect attitude. The movements of its various parts are therefore merely such as are consistent with stability, without producing absolute rigidity.

The two innominate bones, being bound together by powerful ligaments at the pubic articulation, constitute an inverted arch, of which the convexity is directed downwards and forwards, while its piers are turned upwards and backwards, and considerably expanded in relation to the hinder parts of the iliac bones. Between the piers of this inverted arch the sacrum is situated. This bone is in no sense a key-stone to an arch, because, as may readily be seen in antero-posterior transverse section, the sacrum is wider in front than behind, and the superposed weight naturally tends to make the sacrum fall towards the pelvic cavity, and so fit less closely between the innominate bones. The sacrum is in reality an oblique platform, in contact with each innominate

bone through its articular auricular surfaces, and in this position it is suspended by the posterior sacro-iliac ligaments, and kept securely in place by the "grip" due to the irregularity of the opposed surfaces of the two sacro-iliac articulations. Since the weight of the trunk is transmitted to the anterior and upper end of this sacral platform, there is a natural tendency for the sacrum to revolve upon the transverse axis which passes through its sacro-iliac joints. If this were permitted, the promontory of the sacrum would descend downwards and forwards towards the pelvic cavity, as really does occur in certain deformities. This revolution or tilting upwards of the forepart of the sacrum is prevented by the action of the great and small sacro-sciatic ligaments, extending from the ischial tuberosity to the hinder and lower end of the suspended platform of the sacrum. Not only so, but these ligaments, acting on a rigid sacrum, tend to hold up the weight upon the sacral promontory.

The various ligaments passing between the last lumbar vertebra and the sacrum and ilium retain the weight of the trunk in position upon the anterior end of the sacrum, and resist its tendency to slip forwards and downwards towards the pelvic cavity. The entire weight of the trunk and pelvis is transmitted to the heads of the thigh bones in the most advantageous position, both for effectiveness and the strengthening of the inverted innominate arch, for it will be evident that the heads of the femora thrust inwards upon the convex side of the arch, very much at the place where the arches are weakest, viz. at the springing of the arch from its piers. The forces which tend to cause movement of the pelvic bones during parturition act from within the pelvis, and have for their object the increase of the various pelvic diameters, in order that the fœtal head may more readily be transmitted. For this purpose the wedge-like dorsal surface of the sacrum is driven backwards, and a certain amount of extra space may thereby be obtained. An important factor, however, in the increase of the pelvic capacity at this period is found in the relaxation of its various ligaments.

THE ARTICULATIONS OF THE LOWER EXTREMITY.

THE HIP-JOINT.

The human body provides no more perfect example of an enarthrodial diarthrosis than the hip-joint (articulatio coxæ). Combined with all that variety of movement which characterises a multi-axial joint, it nevertheless presents great stability, which has been obtained by simple arrangements, for restricting the range of its natural movements. This stability is of paramount importance for the maintenance of the erect attitude, and the mechanical adaptations whereby this result is obtained are such that the erect attitude may be preserved without any great degree of sustained muscular effort.

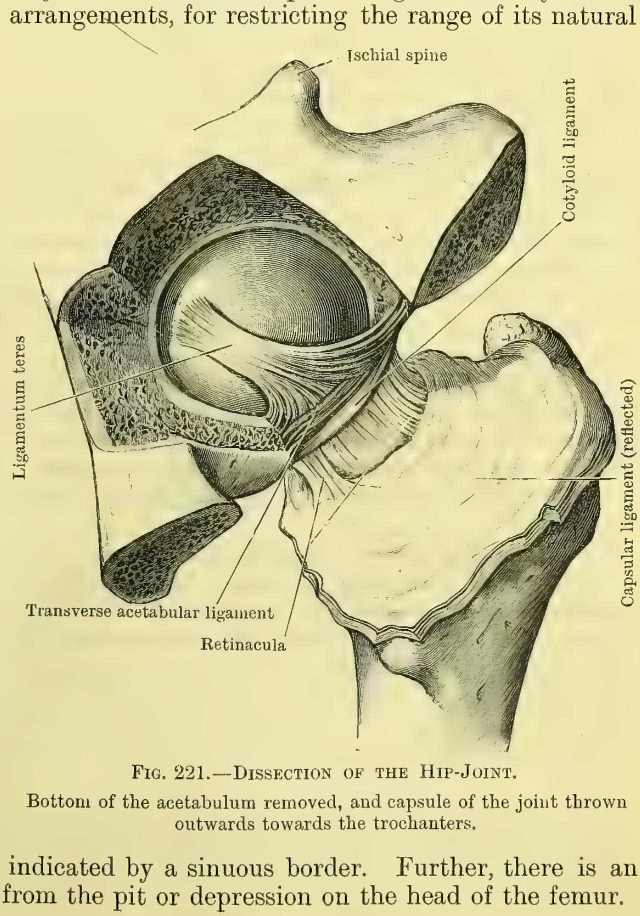


Fig. 221.—Dissection of the Hip-Joint.
Bottom of the acetabulum removed, and capsule of the joint thrown outwards towards the trochanters.

Articular Surfaces.—The head of the femur is globular in shape, and considerably exceeds a hemisphere. It is clothed by hyaline articular cartilage on those parts which come into direct contact with the acetabulum. There is frequently more or less of extension of the articular cartilage from the head to the adjoining anterior part of the neck, an extension which is accounted for by the close and constant apposition of this portion of the neck with the hinder aspect of the ilio-femoral ligament. The limit of the articular cartilage covering the head is indicated by a sinuous border. Further, there is an absence of articular cartilage from the pit or depression on the head of the femur.

The acetabulum is a deep cup-shaped cavity which presents an interruption or notch on its antero-inferior margin. The interior of the cup is lined by a ribbon-like band of articular cartilage which extends to the brim of the cavity, but does not cover the floor of the cup. This articular ribbon-shaped band is widest on its supero-posterior aspect, and narrowest at the anterior margin of the notch.

The **transverse ligament** (lig. transversum acetabuli, Fig. 221) bridges the acetabular notch, and consists of strong transverse fibres which are attached to both of its margins, but more extensively to the postero-inferior. This ligament does not entirely fill the notch, but leaves an open interval between its lower border and the bottom of the notch through which vessels and nerves enter the cup. The acetabular aspect of this ligament constitutes an articular surface.

The acetabulum is deepened by the **cotyloid ligament** (labrum glenoidale, Figs. 221 and 222). This ligament consists of a strong ring of fibro-cartilaginous tissue attached to the entire rim of the cup. The attached surface of the ring is broader than its free edge, and, moreover, the latter is somewhat contracted, so that the ligament grasps the head of the femur which it encircles. Its fibres are partly oblique and partly circular in their direction. By the former it is firmly implanted on the rim of the acetabulum and the transverse ligament of the notch; by the latter the depth of the cup is increased through the elevation of its edge, and its mouth slightly narrowed. By one surface this ligament is also articular.

A **capsule** (capsula articularis, Figs. 220 and 222) completely invests the joint-cavity. This is a fibrous membrane of great strength, although it is not of equal thickness throughout, being considerably thicker on the supero-anterior aspect than at any other part. Unlike the corresponding structure of the shoulder-joint, it does not permit of the withdrawal of the head of the femur from contact with the acetabular articular surfaces, except to a very limited extent. Its fibres are arranged both in the circular and in the longitudinal direction, the former, known as the **zona orbicularis**, being best marked posteriorly, while the longitudinal fibres stand out more distinctly in front, where they constitute special ligaments. Looked at as a whole, the capsule has the following attachments:—*superiorly* it surrounds the acetabulum, on the upper and hinder aspects of which it is attached directly to the innominate bone, while on the front and lower aspects it is attached to the non-articular surfaces of the cotyloid and transverse ligaments; *inferiorly* it encircles the neck of the femur, where it is attached in front to the anterior intertrochanteric line; above, to the inner aspect of the root of the great trochanter; below, to the lower part of the neck of the femur, in close proximity to the small trochanter; behind, to the line of junction of the outer and middle thirds of the neck of the femur. It is a matter of some importance to note that only part of the posterior surface of the neck of the femur is enclosed within the capsule. The femoral attachments of the capsule vary considerably in their strength, being particularly firm above and in front, but much weaker below and behind, where the orbicular fibres are well seen. Many fibres of the capsule are reflected from its deep aspect upwards upon the neck of the femur, where they form ridges, and to these the term **rectinacula** (Fig. 221) is applied.

The longitudinal fibres of the capsule are arranged so as to form certain definite bands, viz.:—

(1) The **ilio-femoral ligament** (lig. ilio-femorale, Fig. 222) consists of a triangular set of fibres attached above, by their apex, to the lower part of the anterior inferior iliac spine and the immediately adjoining part of the rim of the acetabulum, and below, by their base, to the anterior intertrochanteric line of the femur. This ligament is the thickest part of the capsule, but its sides are more pronounced than its centre, especially towards its base. Consequently the ilio-femoral band presents some resemblance to an inverted Y (⅄), and therefore it is very generally known as the Y-shaped ligament of Bigelow.

The outer or upper limb of the ilio-femoral ligament may be somewhat extended by the inclusion of additional longitudinal fibres, and described as the **ilio-trochanteric** ligament (lig. ilio-trochantericum). This band arises from the anterior part of the dorsum of the acetabulum, and extends to the femoral neck, close to the anterior end of the inner surface of the great trochanter.

(2) The **pubo-femoral** or **pubo-capsular ligament** (lig. pubo-femorale v. pubo-capsulare, Fig. 222) is composed of some bands of fibres of no great strength, which extend from the outer end of the horizontal ramus of the pubis, the ilio-pectineal eminence, the obturator crest and the obturator membrane, to lose themselves for the most part in the capsule, although a certain proportion of them may be traced to the inferior aspect of the femoral neck, where they adjoin the lower attachment of the Y-shaped ligament.

(3) The **ischio-capsular ligament** (lig. ischio-capsulare, Fig. 220) consists of a broad band of short, fairly strong longitudinal fibres, which, by their upper ends, are attached to the ischium between the small sciatic notch and the obturator foramen, while their lower ends become merged in the zona orbicularis of the general capsule.

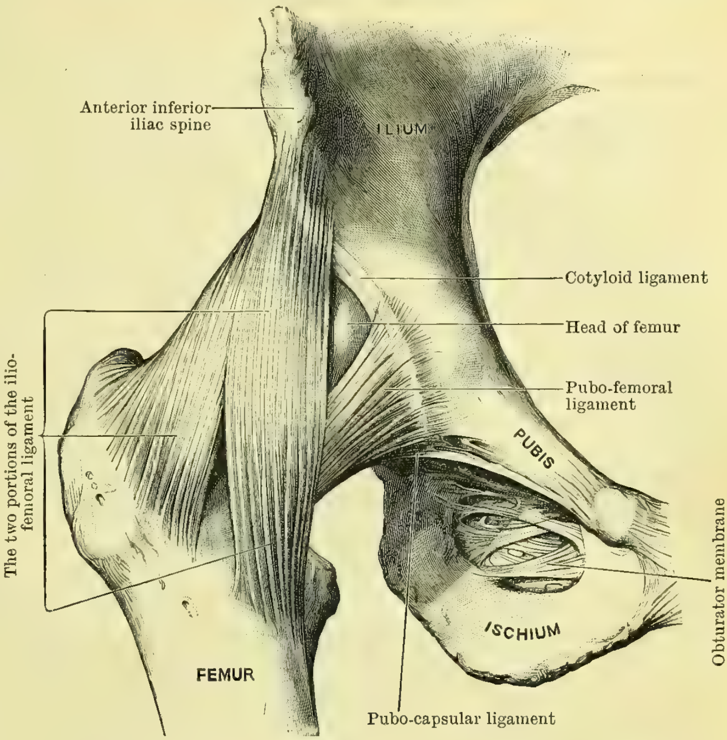


Fig. 222.—Dissection of the Hip-Joint from the front.

Within the capsule, and quite distinct from it, there are the ligamentum teres and the Haversian gland.

The **interarticular ligament** (lig. teres femoris, Fig. 221) is a strong, somewhat flattened band of fibrous tissue, attached by one end to the upper half of the pit or depression on the head of the femur. By its inner end it is attached to the lower edge of the articular surface of the transverse ligament, with extensions to the opposite borders of the acetabular notch, but chiefly to the hinder or ischial border. This ligament varies very greatly in its strength and development in different subjects, and in certain rare cases it is absent.

The so-called **Haversian gland** occupies the bottom or non-articular area of the acetabulum. It consists of a mass of fat covered by synovial membrane. This pad of fat is continuous with the extra-capsular fat through the passage subjacent to the transverse ligament of the notch.

A **synovial membrane** lines the capsule from which it is reflected to the neck of the femur along a line which corresponds to the femoral attachments of the capsule. Thus the synovial membrane clothes more of the femoral neck anteriorly than in any other position. Posteriorly, where the capsule is feebly attached to the neck of the femur, the synovial membrane may be seen from the outside of the capsule. The synovial membrane extends close up to the articular margin of the head of the femur, and on the upper and lower aspects of the neck it is gathered into loose folds upon the retinacula. These folds or plications are best marked along the line of synovial reflection, and do not reach as far as the femoral head. At its acetabular end the synovial membrane is prolonged from the inside of the capsule to the outer non-articular surface of the cotyloid and transverse ligaments, upon which it is continued as a lining for their acetabular or articular surfaces, and further, it provides a covering for the fat at the bottom

of the acetabular fossa, as well as a complete tubular investment for the ligamentum teres.

Occasionally the **synovial bursa**, which is subjacent to the tendon of the ilio-psoas muscle, communicates with the interior of the hip-joint through an opening in the anterior wall of the capsule (Fig. 222), situated between the pubo-femoral ligament and the inner or lower limb of the ilio-femoral ligament.

Movements at the Hip-Joint.—The movements which occur at the hip-joint are those of a multiaxial joint. These are **flexion, extension, abduction, adduction, rotation,** and **circumduction.** The range of each of these movements is less extensive than in the case of the shoulder-joint, because, at the hip, the freedom of movement is subordinated to that stability which is essential alike for the maintenance of the erect attitude and for locomotion. When standing at rest in the erect attitude the hip-joint occupies the position of **extension,** and as the weight of the trunk is transmitted in a perpendicular which falls behind the centres of the hip-joints, both the erect attitude and the extended position are maintained to a large extent mechanically, without sustained muscular action, by means of the tension of the ilio-femoral ligament. Moreover, the tension of this ligament is sustained by the pressure of the front of the head and neck of the femur against its synovial surface. In this association of parts it is important to note that the articular cartilage of the femoral head may be, and in certain races is, prolonged to the front of the femoral neck; and further, that the constant friction does not destroy the synovial lining of the capsule. Again, the same mechanism which preserves the erect attitude prevents an excessive degree of extension or dorsiflexion. In movement forwards, *i.e.* ventral **flexion,** the front of the thigh is approximated to the anterior abdominal wall. The amount of this movement depends upon the position of the knee-joint, because when the latter is flexed the thigh may be brought into contact with the abdominal wall, whereas when the knee-joint is straightened (*i.e.* extended) the tension of the hamstring muscles greatly restricts the amount of flexion at the hip-joint. **Abduction** and **adduction** are likewise much more restricted than at the shoulder-joint. **Abduction** is brought to a close by the tension of the pubo-femoral band and the lower part of the capsule, and, in addition, the upper aspect of the neck of the femur locks against the margin of the acetabulum. Excessive **adduction** is prevented by the tension of the upper band of the ilio-femoral ligament and the upper part of the capsule. **Rotation** or movement in a longitudinal axis may be either inwards, *i.e.* towards the front, or outwards, *i.e.* toward the back. In the former the movement is brought to a close by the tension of the ischio-capsular ligament and back part of the capsule, aided by the muscles on the back of the joint; in the latter—rotation outwards—the chief restraining factor is the outer or upper limb of the ilio-femoral ligament. The total amount of rotation is probably less than 60°.

Circumduction is only slightly less free than at the shoulder, but it is complicated by the preservation of the balance upon one foot.

The value and influence of the ligamentum teres are not easily estimated, because it may be absent without causing any known interference with the usefulness of the joint. In the erect attitude this ligament lies lax between the lower part of the femoral head and the acetabular fat. In the act of walking it is rendered tense at the moment when the pelvis is balanced on the summit of the supporting femur. Analysis of this position shows the femur to be adducted, with probably, in addition, a small amount of flexion (*i.e.* bending forwards) and internal rotation. Again, this ligament is said to be tense when the thigh is rotated outwards. The equivalent of this movement is doubtless found in the rotation of the pelvis, which occurs in the act of walking at the moment of transition from the toe of the supporting foot to the heel of the advancing foot. The interest connected with this ligament is perhaps morphological rather than physiological. It is believed by some to represent the tendon of a muscle which in birds occupies a position external to the joint capsule.

THE KNEE-JOINT.

The knee-joint (articulatio genu) is the largest articulation in the body, and its structure is of a very elaborate nature. The part it plays in maintaining the erect attitude materially influences its construction, and special arrangements are provided for the mechanical retention of the joint in the extended position, in view of the fact that the line of gravity falls in front of the centre of the articulation. Its principal axis of movement is in the transverse direction, consequently it belongs to the ginglymus or hinge variety of the diarthroses. At the same time a slight amount of rotation of the tibia in its long axis is permitted during extreme flexion; but while this fact is of considerable importance in the study of certain accidents to which the joint is liable, as well as in the study of its comparative morphology, it is not sufficiently pronounced to interfere with its classification as a hinge-joint.

Articular surfaces pertaining to the femur, tibia, and patella, enter into the formation of the knee-joint. The articular surface of the femur extends over a large part of both condyles, and may be divided into patellar and tibial portions

by faintly-marked, almost transverse grooves, which pass across the articular surface immediately in front of the intercondylar notch. As a rule marginal indentations of the articular surface render the positions of these transverse grooves more distinct.

The **patellar portion** (Fig. 223) is situated anteriorly, and is common to both condyles, although developed to a larger extent in association with the outer condyle, on which it ascends to a higher level than on the inner condyle. This surface is trochlear, and forms a vertical groove bordered by prominent lateral borders.

The **tibial portion** of the articular surface of the femur is divided into two articular areas, in relation to the inferior aspects of the two condyles, by the wide non-articular intercondyloid notch. These two surfaces are for the most part parallel, but in front the internal tibial surface turns obliquely outwards as it passes into continuity with the patellar trochlea, while posteriorly, under certain circumstances, *e.g.* the squatting posture, the articular surface of the inner condyle may extend to the adjoining portion of the popliteal area of the bone.

When the joint is in the position of extreme flexion, the patella is brought into direct contact with that part of the articular surface on the inner condyle which bounds the intercondyloid notch upon its inner and anterior aspects. This relationship is indicated by the presence of a distinct semilunar facet on the cartilage in that situation (Fig. 223). The articular surface of the femur may therefore be regarded as presenting **femoro-patellar** and **femoro-tibial areas.**

The **patella** presents on its posterior aspect a transversely-elongated oval articular facet and an inferior rough, triangular, non-articular area. The articular facet is divided into two principal lateral portions by a prominent rounded vertical ridge. Of these the outer is the wider. A less pronounced and nearly vertical ridge marks off an additional facet called the internal perpendicular facet, close to the inner margin of the articular surface. Two faint transverse ridges cut off narrow upper and lower facets from the general articular surface without encroaching on the narrow innermost vertical facet (Goodsir) (Fig. 223).

The head of the **tibia** presents on its superior aspect two condylar articular surfaces, separated from each other by a non-articular antero-posterior area, which is wider in front and behind than in the middle, where it is elevated to form a bifid tibial spine.

The **external condylar facet** is slightly concavo-convex from before backwards, and slightly concave transversely. This surface is almost circular, and extends to the free external border of the tibial head, where it is somewhat flattened. Posteriorly the articular surface is prolonged downwards on the tuberosity in relation to the position occupied by the tendon of the popliteus muscle. The **internal condylar facet** is oval in outline, and distinctly concave both in its antero-posterior and transverse diameters.

Ligaments.—Like all diarthroses, this joint is invested by an envelope or **capsule** (capsula articularis), which does not, however, entirely surround the joint-cavity, for it is absent as a fibrous membrane above the joint-cavity, subjacent to the tendon of the quadriceps extensor muscle. Its specially-named bands are not of themselves sufficient to form a complete investment, and a capsular membrane, which largely consists of augmentations from the fascia lata and the tendons of surrounding muscles, supplies the defective areas. Thus, anteriorly, on each side of the patella and the ligamentum patellæ, expansions of the vasti tendons and fascia lata, constituting **lateral patellar ligaments**, are evident. On the outer side of the joint the external lateral ligament is hidden within a covering derived from the ilio-tibial band of the fascia lata. On the inner side expansions from the tendons of the sartorius and semi-membranosus muscles augment the capsule, which here becomes continuous with the internal lateral ligament. Posteriorly the capsule also receives augmentation from the tendon of the semi-membranosus muscle, but it is very thin subjacent to the origins of the gastrocnemius muscle, where it covers the hinder parts of the condyles. Not unfrequently the capsule presents an opening of communication between the interior of the joint-cavity and a bursa which lies under cover of the inner head of the gastrocnemius muscle.

The **anterior ligament** (lig. patellæ, Fig. 223), also called the ligamentum

patellæ, is a powerful flattened band, attached superiorly to the apex and adjoining margins of the patella, and inferiorly to the rough anterior tuberosity at the upper end of the shaft of the tibia. This ligament also serves as a tendon of insertion for the quadriceps extensor muscle, and a certain number of the fibres of the tendon may be observed to descend as a thin fibrous covering for the anterior surface of the

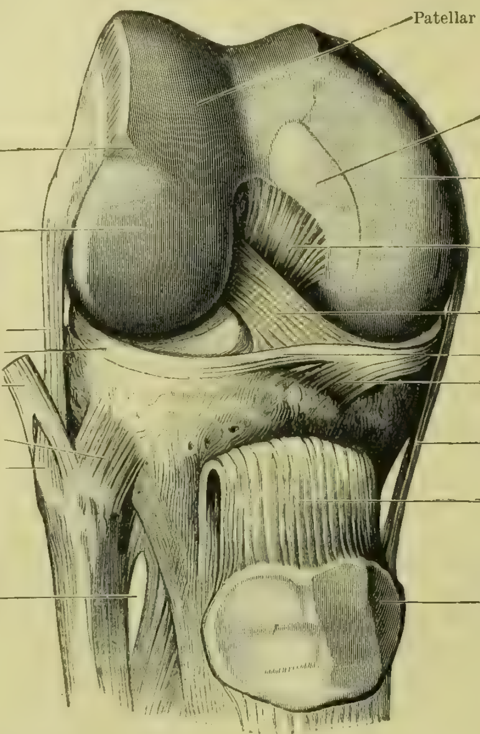


Fig. 223.—Dissection of the Knee-Joint from the Front: Patella thrown down.

patella. The deep surface of the tendon is separated from the front of the head of the tibia by a synovial bursa, and above this it rests upon the infrapatellar pad of fat, which is placed between the tendon and the synovial membrane of the joint.

The **posterior ligament** (Fig. 224) is a compound structure of unequal strength, and those portions by which it establishes continuity with the lateral parts of the capsule are remarkably thin. It is attached superiorly to the popliteal surface of the femur, close to the intercondyloid notch, with lateral extensions to the non-articular areas immediately above the posterior articular margins of the two condyles, where it is closely associated with the origins of the gastrocnemius muscle.

Inferiorly it is attached to the rough non-articular posterior border of the head of the tibia, where, to its fibular side, it presents an opening of exit for the tendon of the popliteus muscle (Fig. 224).

The tendon of insertion of the semi-membranosus muscle contributes an important expansion which augments the posterior ligament on its superficial aspect. This expansion—**ligamentum posticum Winslowii**—passes obliquely upwards and outwards to lose itself in the general ligament, but it is most distinct in the region between the femoral condyles, where it may present upper and lower arcuate borders. A number of vessels and nerves perforate this ligament, and hence it presents a number of apertures.

The **internal lateral ligament** (lig. collaterale tibiale, Fig. 223) is a well-defined strong flat band which is applied to the inner side of the knee-joint, and is rather wider in the middle than at either end. It is frequently regarded as consisting of two portions—an anterior or long portion and a posterior or short one. The two parts arise close together from the non-articular inner surface of the inner condyle, immediately below the adductor tubercle. The **short** or **posterior portion** descends slightly backwards, to be attached to the postero-internal aspect of the inner part of

the tibia above the groove for the semi-membranosus tendon. The **long or anterior portion** inclines somewhat forwards, and descending superficially to the tendon of the semi-membranosus, it is continued downwards, to be attached to the upper part of the inner surface of the shaft of the tibia below the level of the anterior tuberosity.

On its superficial aspect the internal lateral ligament is augmented by prolongations from the tendons of the semi-membranosus and sartorius muscles, but is separated by a bursa from the tendons of gracilis, semi-tendinosus and sartorius. Its deep surface is adherent to the convex edge of the internal semilunar cartilage, but lower down the inferior internal articular vessels intervene between the ligament and the shaft of the tibia.

The **external lateral ligament** (lig. collaterale fibulare, Fig. 223), sometimes called the ligamentum laterale externum longum, is a distinct rounded band which is under cover of the ordinary capsule, and yet well separated from the joint-cavity by intervening objects. It is attached superiorly to a tubercle on the outer surface of the external condyle, immediately above the groove occupied by the tendon of the popliteus muscle, superficial to which the ligament descends. By its lower end it is attached to the outer side of the head of the fibula, in front of the styloid process. In its course vertically downwards it splits the tendon of insertion of the biceps flexor cruris (Fig. 223), the portions of which are fixed to the head of the fibula on either side of the ligament, and a bursa may intervene between the tendon and the ligament. The inferior external articular vessels pass forwards subjacent to this ligament and above the head of the fibula. Unlike the internal ligament, it is not attached to the corresponding semilunar cartilage.

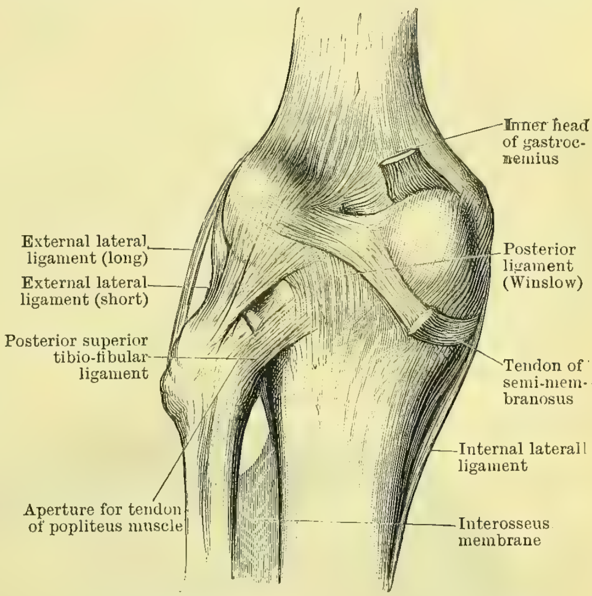


FIG. 224.—DISSECTION OF KNEE-JOINT FROM BEHIND.

The **ligamentum laterale externum breve seu posticum** (Fig. 224) is an inconstant structure which is attached by its upper end immediately behind the preceding, and subjacent to the outer head of the gastrocnemius muscle. It likewise descends superficial to the popliteal tendon and is affixed inferiorly into the styloid process of the fibula.

The **intra-articular structures** of the knee-joint are more important and more numerous than in any other joint of the body.

The **crucial ligaments** (ligamenta cruciata genu) are two strong, rounded, tendinous bands which extend from the non-articular area on the upper surface of the head of the tibia to the non-articular sides of the intercondyloid notch of the femur These interarticular ligaments are distinguished from each other as the anterior or external and the posterior or internal. They cross each other like the limbs of an X, yet they remain distinct throughout, and each has its own partial synovial covering. They lie within the capsule of the joint, and extend between non-articular surfaces in relation to the longitudinal axis of the limb.

The **ligamentum cruciatum anterius** (Figs. 223 and 225) is attached inferiorly to the inner part of the rough depressed area in front of and close to the spine of the tibia. It passes obliquely upwards, outwards, and backwards to the inner non-articular surface of the external condyle, where it finds attachment far back in the posterior part of the intercondyloid notch. This ligament is tense in the position of extension, and therefore it assists in maintaining the erect attitude.

The **ligamentum cruciatum posterius** (Figs. 223 and 225) is somewhat shorter than the preceding. It is attached inferiorly to the hinder part of the depressed

surface behind the spine of the tibia and close to the popliteal notch. Its fibres pass obliquely upwards, forwards, and inwards, to be inserted into the outer non-articular surface of the inner condyle, far forwards towards the anterior margin of the intercondyloid notch. It is rendered tense in the position of flexion.

The **semilunar interarticular fibro-cartilages** are two in number—an inner and an outer—placed horizontally between the articular surfaces of the femur and tibia. In general outline they correspond to the circumferential portions of the tibial facets upon which they rest. Each has a thick, convex, fixed border in relation to the periphery of the joint, and a thin, concave, free border directed towards the interior of the joint. Neither of them is sufficiently large to cover the whole of the tibial articular surface upon which it rests. The upper and lower surfaces of each semilune are smooth and free, and each cartilage terminates in an anterior and a posterior fibrous horn or cornu.

The **internal semilunar fibro-cartilage** (meniscus medialis, Fig. 225) forms very nearly a semicircle. It is attached by its anterior horn to the non-articular surface on the head of the tibia, in front of the tibial attachment of the anterior crucial ligament, and by its posterior horn to the non-articular surface immediately in front of the tibial attachment of the posterior crucial ligament. The deep or hinder part of the internal lateral ligament is attached to its periphery.

The **external semilunar fibro-cartilage** (meniscus lateralis, Fig. 225) is attached by its anterior horn to the non-articular surface of the tibia in front of the tibial spine, where it is placed to the outer side, and partly under cover of the tibial end of the anterior crucial ligament. By its posterior horn it is attached to the interval between the two tubercles which surmount the tibial spine, *i.e.* in front of the attachment of the posterior horn of the internal semilunar cartilage. This fibro-cartilage, with its two horns, therefore forms almost a complete circle. Posteriorly it is attached by its periphery to the posterior ligament, but on the outer side it is separated from the external lateral ligament by the tendon of the popliteus muscle, and on this aspect its periphery is free.

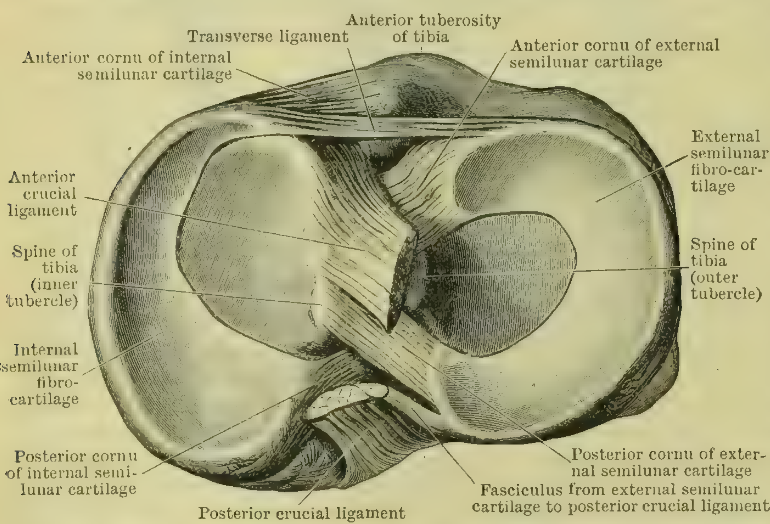


FIG. 225.—UPPER END OF TIBIA, WITH SEMILUNAR CARTILAGES AND ATTACHED PORTIONS OF CRUCIAL LIGAMENTS.

The two horns of the external semilune are embraced by the two horns of the internal one, and, while the anterior crucial ligament has its tibial attachment almost between the anterior horns of the two semilunes, the tibial attachment of the posterior crucial ligament is situated behind the posterior horns of the two semilunes.

Both semilunes possess certain accessory attachments. Thus the external semilune sends a large bundle of fibres from its convex posterior border to augment the posterior aspect of the posterior crucial ligament, by which these fibres are conducted to the femur. Again, the convex or peripheral margins of each semilune possess certain attachments to the deep surface of the capsule on its inner and posterior aspects, as has already been explained, but, in addition, they are attached to the non-articular circumference of the tibial head by short fibrous bands known as the **ligamenta coronaria**. Lastly, a rounded band which varies in strength, the **transverse ligament** (lig. transversum genu, Figs. 223 and 225), stretches between the anterior

convex margins of the two semilunes, crossing the front part of the non-articular area on the tibial head in its course.

The **synovial membrane** of the knee-joint is not only the largest, but the most elaborately arranged of its kind in the body. It not only lines the capsule, but it forms a more or less extensive covering for the intracapsular ligaments and the free surface of the **infra-patellar pad of fat.** This pad acts as a wedge which fits into the interval between the patella, tibia, and femoral condyles, and the synovial membrane upon its surface forms a band or fold which extends from below the level of the patellar articular surface to the anterior part of the intercondyloid notch. This is in no sense a ligament, although it is named the **ligamentum mucosum,** or plica synovialis patellaris. At its femoral end it is narrow and attenuated, but at its patellar end it expands laterally to form wing-like fringes or membranes—the **alar ligaments** (plicæ alares)—which are often distinguished from each other as the inner (plica aliformis medialis) and the outer (plica aliformis lateralis). These folds are more or less loaded with fat.

Apart from these special foldings, the synovial membrane lines the deep surface of the common extensor tendon, and extends upwards for a variable distance above the patella. This extension of the joint-cavity almost always communicates with a large bursa situated still higher on the front of the femur. Tracing the synovial membrane downwards, it will be found to cover both surfaces of the semilunar fibro-cartilages. The peripheral or convex margins of these cartilages are only covered by this membrane where they are unattached to the capsule. A prolongation invests the intracapsular portion of the tendon of the popliteus muscle, and separates this tendon from the back part of the tibial head, besides intervening between the external semilune and the head of the tibia.

From the back part of the joint-cavity the synovial membrane extends forwards, and provides a partial covering for the crucial ligaments.

This somewhat complicated arrangement of the synovial membrane may be readily comprehended if it be borne in mind that it really represents the fusion of three separate synovial membranes, which in some animals are permanently distinct. These are indicated in the two femoro-tibial and the single femoro-patellar parts of the articulation.

The joint-cavity may communicate with **bursæ** situated in relation to the inner head of the gastrocnemius muscle and the tendon of the semi-membranosus muscle, besides the large supra-patellar bursa already described. Lastly, there may be intercommunication between this joint-cavity and that of the superior tibio-fibular articulation.

Movements at the Knee-Joint.—In studying the movements which may occur at the human knee-joint, it is necessary to bear in mind that the lower limb of man is primarily required for purposes of support and locomotion. The principal requirement of the former function is stability accompanied by rigidity, whereas in the latter function the special desideratum is, regulated and controlled mobility. Thus, in the same joint, two entirely opposite conditions have to be provided. The stable conditions of support are chiefly concerned in the maintenance of the erect attitude, and the mechanism associated therewith does not call for the exertion of a large degree of sustained muscular effort.

In standing erect the attitude of the limb is that of extension, which mainly concerns the femoro-tibial parts of the joint. In this position the force of gravity acts along a vertical line which falls in front of the transverse axis of the joint, and therefore any tendency to flexion, *i.e.* bending backwards, is mechanically counteracted by the application of a force which tends to produce bending forwards (so-called over-extension). This, however, is absolutely prohibited in normal states of the joint, by the tension of the posterior and lateral ligaments aided by the anterior crucial ligament. The value of this fact may be seen by observing the effect produced by giving the joint a sudden push from behind, which causes an immediate reversal of the positions of the transverse and vertical axes, whereby the body weight at once produces flexion of the joint.

The semilunar cartilages and the infrapatellar pad of fat also assist in maintaining extension, by reason of their close adaptation to, and packing round the condyles as these rest upon the tibia. The anterior margin of the intercondyloid fossa is also brought into contact with the front of the anterior crucial ligament.

In the position of extension the patella is retained at a high level in relation to the trochlear surface of the femur, so that the lower articular facets of the patella are in contact with the trochlea.

During locomotion the movements of the knee-joint are somewhat intricate, for both the femoro-tibial and the femoro-patellar sections of the joint are brought into action. The principal movement which results is flexion, with which there is associated, both at its beginning and

ending, a certain amount of screw movement or rotation. Flexion and rotation occur at the femoro-tibial sections of the joint, whereas the movement at the femoro-patellar portion produces a regulating and controlling influence upon flexion.

Taking these factors separately, we observe that each condyle adapts itself to a shallow cup formed by the head of the tibia and the corresponding semilunar cartilage, and as the two condyles move simultaneously and parallel to each other, there is more than the characteristic hinge-joint action, for each condyle glides and rolls in its cup "like a wheel restrained by a drag" (Goodsir) when the movement of bending occurs. Thus the different parts of the condyles are successively brought into relation with the transverse axis of the joint while it passes from extension to flexion and *vice versa*. From the fact that the internal condyle is longer than the external, it is believed that extension is completed by a movement of rotation whereby the joint becomes locked, and the anterior crucial, the posterior and the lateral ligaments, become tense. A similar rotation initiates the movement of flexion, and unlocks the joint by relaxing the ligaments just mentioned.

Since the tibia and foot are fixed in the act of walking, it is the femur which rotates upon the tibia in passing from extension to flexion and *vice versa*; and as relaxation of the ilio-femoral ligament is essential for this rotation, some observers are of opinion that the body weight falls behind the transverse axis of the knee-joint, as in the case of the hip-joint, and consequently that extension of the knee-joint is maintained by the ilio-femoral ligament, as it is not possible to bend the knee without first having bent the hip-joint.

During flexion and extension the semilunar cartilages glide along with the condyles, so as to maintain their close adaptation and preserve their value as packing agents. When the movement of flexion is completed, the condyles are retained upon the tibia, and prevented from slipping off by the tension of the posterior crucial ligament. In this position a small degree of rotation of the tibia, both inwards and outwards, is also permissible.

The regulating and controlling influence of the femoro-patellar portion of the articulation is brought into play during the movements of flexion and extension. In the latter position the inferior pair of patellar facets is in apposition with the upper part of the femoral trochlea. As flexion advances, the middle pair of facets adapt themselves to a deeper area of the trochlea, into which the patellar keel fits. When flexion is still further advanced, the upper pair of patellar facets will be found fitting into that part of the trochlea adjoining the intercondyloid notch; and finally, when flexion is complete, the patella lies opposite the intercondyloid notch, while the forward thrust of the longer internal condyle brings its semilunar facet (Goodsir) into apposition with the somewhat vertical facet at the inner border of the patella. The wedge-like influence of the patella is most marked, for it is only in the position of extension that it can be moved from side to side. The movements of the patella may be described as gliding and co-aptation, as it slips or rocks from one pair of facets to another in its progress along the trough of the femoral trochlea.

THE TIBIO-FIBULAR JOINTS.

The upper and lower ends of the fibula articulate with the tibia. Primarily, the fibula is required to form a strong lateral support for the ankle-joint, and therefore its articulations are so arranged as to provide a certain amount of elasticity without any sacrifice of the rigidity necessary for security. Hence the amount of movement is very small, but what there is, enables these joints to be classified as arthrodial diarthroses.

The **superior tibio-fibular joint** (articulatio tibio-fibularis) is formed, on the one hand by a flat oval or circular facet which is situated upon the postero-external aspect of the outer tuberosity of the head of the tibia, and is directed downwards and backwards; on the other, by a similar facet on the upper surface of the head of the fibula in front of the styloid process.

A fibrous **capsule** (capsula articularis, Fig. 224) invests the joint, and it may be regarded as holding the articular surfaces in apposition, although certain special bands receive separate designations. Occasionally there is an opening in the capsule by which communication is established between the joint-cavity and the knee-joint through the intermediation of the synovial prolongation, subjacent to the tendon of the popliteus muscle.

The **anterior superior tibio-fibular ligament** (lig. capituli fibulæ anterius, Fig. 223) is a strong flat band whose fibres extend from the anterior aspect of the fibular head, upwards and inwards, to the adjoining part of the tuberosity of the tibia.

The **posterior superior tibio-fibular ligament** (lig. capituli fibulæ anterius, Fig. 224) is a similar, but weaker band, passing upwards and inwards from the posterior aspect of the fibular head to the posterior aspect of the outer tuberosity of the tibia, where they are attached immediately below the opening in the capsule of the knee-joint, from which the tendon of the popliteus muscle escapes.

Equally strong but much shorter bands are found on the superior and inferior aspects of the joint. The former is intimately associated with the tendon of the biceps which strengthens the upper aspect of the joint and here also is found the occasional opening by which it communicates with the knee-joint.

The **synovial membrane** is in certain cases continuous with that of the knee-joint in the manner already described.

The **interosseous membrane** (membrana interossea cruris, Figs. 224, and 226) plays the part of an accessory ligament both for the upper and the lower tibio-fibular joint. It is attached to the interosseous borders on the shafts of the tibia and fibula, and binds them together. The general direction of its fibres is from the tibia downwards and outwards to the fibula, but many fibres pass in the opposite direction. The membrane may extend upwards until it comes into contact with the ligaments of the superior tibio-fibular joint, but there is always a vertical oval aperture in its upper part for the forward passage of the anterior tibial vessels. This aperture (Fig. 224), which is about one inch long, adjoins the shaft of the fibula at a point rather less than one inch below its head. Towards the lower end of the leg the distance between the tibia and the fibula rapidly diminishes, and consequently the width of the interosseous membrane is correspondingly reduced, so that it is tense throughout its entire length. In the lower part of the membrane there is a small opening for the passage of the anterior perforating vessels. There is no sharply-marked demarcation between the interosseous membrane and the interosseous ligament which connects the lower ends of the tibia and fibula—the one, indeed, may be said to run into the other.

The **inferior tibio-fibular joint** (syndesmosis tibio-fibulare) is not on all occasions provided with articular cartilage, so that it may either be a separate articulation, or it may merely present a series of ligaments which are accessory to the ankle-joint, because it is clear that, under any circumstances, the object aimed at in this articulation is to obtain additional security for the ankle-joint. The articular surface on the tibia, when present, constitutes a narrow articular strip on the outer side of the lower end of the bone, and the joint-cavity is practically an upward extension of the ankle-joint. The corresponding fibular facet is continuous with the extensive articular area, by means of which the fibula articulates with the astragalus. By far the greater part of the opposing surfaces of tibia and fibula are, however, non-articular and rough.

The supporting **ligaments** are of great strength.

The **anterior inferior tibio-fibular ligament** (lig. malleoli lateralis anterius, Fig. 229) consists of strong fibres which pass obliquely downwards and outwards from the front of the lower end of the tibia to the front of the external malleolus.

The **posterior inferior tibio-fibular ligament** (lig. malleoli lateralis posterius, Figs. 226 and 227) is equally strong, and passes in a similar direction between corresponding posterior surfaces.

A **transverse inferior tibio-fibular ligament** (Figs. 226 and 227) stretches, in the direction indicated by its name, between the posterior inferior border of the tibia and the upper end of the pit on the inner and posterior aspect of the external malleolus.

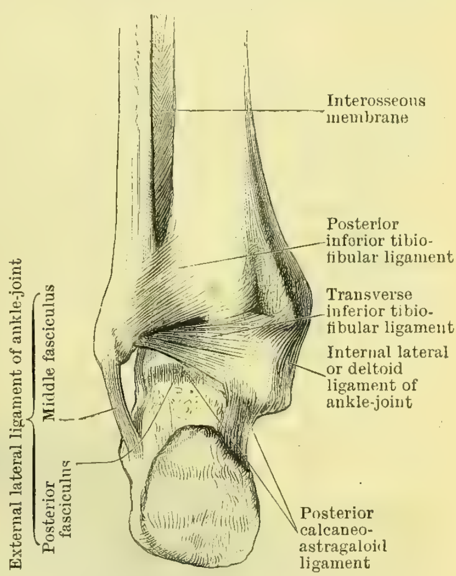


FIG. 226.—POSTERIOR ASPECT OF INFERIOR TIBIO-FIBULAR AND ANKLE-JOINTS.

An **interosseous ligament** (Fig. 227), powerful and somewhat extensive, connects the contiguous rough non-articular surfaces. Superiorly, as already mentioned, it is continuous with the interosseous membrane. Anteriorly and posteriorly it comes into contact with the more superficial ligaments. Inferiorly it descends until it comes into intimate association with the joint-cavity.

A **synovial membrane** is found lining the small joint-cavity, but it is always a direct prolongation from that which lines the ankle-joint.

JOINTS OF THE FOOT.

THE ANKLE-JOINT.

The ankle-joint (articulatio talo-cruralis) is a ginglymus variety of a diarthrosis. The bones which enter into its formation are the lower ends of the tibia and fibula, with the articular areas on the upper, lateral, and inner surfaces of the astragalus. The tibia and fibula, aided by the transverse inferior tibio-fibular ligament, form a three-sided socket within which the astragalus is accommodated. The roof or highest part of the socket, which is wider in front than behind, is formed chiefly by the quadrilateral articular surface which characterises the lower end of the tibia, but towards its postero-external margin the transverse inferior tibio-fibular ligament assists in its formation. Here also the tibial articular surface is continuous with the narrow articular facet already described as forming part of the inferior tibio-fibular joint. The inner wall of the socket is formed by the articular facet on the outer side of the internal malleolus, and there is no interruption of the articular cartilage between the roof and inner wall. The outer wall of the socket is quite separate from the foregoing parts, and consists of a large triangular facet upon the inner side of the external malleolus. This facet is situated immediately in front of the deep pit which characterises the posterior part of this surface of the fibula.

A small lunated facet is frequently found upon the anterior surface of the lower end of the tibia, particularly among those races characterised by the adoption of the "squatting" posture. When this facet exists it is continuous with the anterior margin of the roof of the socket, and it articulates with a similar facet upon the upper surface of the neck of the astragalus in the extreme flexion of the ankle-joint which "squatting" entails.

The articular surface upon the body of the astragalus adapts itself to the tibio-fibular socket, and presents articular facets corresponding to the roof and sides of the socket. Thus the superior surface of the astragalus possesses a quadrilateral articular area, wider in front than behind, distinctly convex in the antero-posterior direction, and slightly concave transversely. In addition, towards its postero-external margin, there is also a narrow antero-posterior facet corresponding to the transverse inferior tibio-fibular ligament. The articular cartilage of this upper surface is continued without interruption to the tibial and fibular sides of the bone, although the margins of the superior area are sharply defined from the lateral facets, the outer of which is triangular in outline, while the inner is pyriform, but in each case the surface is vertical.

Ligaments.—The ligaments form a complete investment for the joint, *i.e.* a **capsule** in which the individual parts vary considerably in strength, and are described under separate names.

The **anterior ligament** (Fig. 229) is an extremely thin membrane, containing very few longitudinal fibres. It extends from the lower border of the tibia to the upper border of the head of the astragalus, passing in front of a pad of fat which fills up the hollow above the neck of that bone.

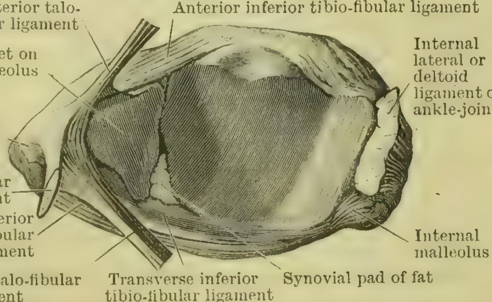


FIG. 227.—ARTICULAR SURFACES OF TIBIA AND FIBULA WHICH ARE OPPOSED TO THE ASTRAGALUS.

The **posterior ligament** (Fig. 226) is attached to contiguous non-articular borders of the tibia and astragalus. Many of its fibres radiate inwards from the external malleolus. This aspect of the joint is strengthened by the strong, well-defined, transverse ligament already described in connection with the inferior tibio-fibular joint.

The **external lateral ligament** (Figs. 227 and 229) is very powerful, and is divisible

into three fasciculi, which are distinguished from each other by names descriptive of their chief points of attachment.

The *anterior fasciculus* (lig. talo-fibulare anterius) is the shortest. It extends from the anterior border of the external malleolus to the astragalus immediately in front of its external articular surface.

The *middle fasciculus* (lig. calcaneo-fibulare) is a strong and rounded cord. It is attached by one end to the front of the tip of the external malleolus, and by the other to the outer side of the os calcis, immediately above the groove for the peroneal tendons.

The *posterior fasciculus* (lig. talo-fibulare posterius) is the strongest. It runs transversely between the lower part of the fibular fossa on the inner aspect of the malleolus and the posterior surface of the astragalus, where it is attached to the external tubercle and the adjoining rough surface. Sometimes this tubercle is detached from the astragalus, and represents a separate bone—the *os trigonum.*

The **internal lateral ligament** (lig. deltoideum, Figs. 227 and 228) has the general shape of a delta, and is even stronger than the external ligament. It is attached above

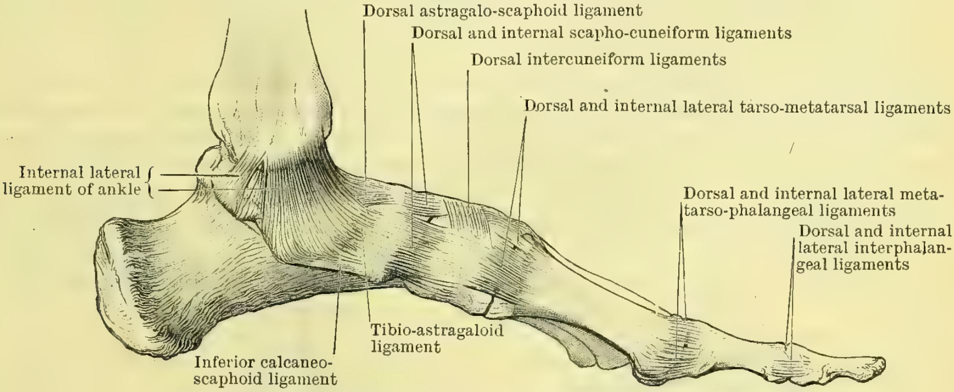


Fig. 228.—Ligaments on Inner Aspect of Ankle and Foot.

to a marked impression on the lower part of the internal malleolus, and below, in a continuous layer, to the scaphoid, astragalus, and os calcis. In it we may recognise the following special bands—(*a*) the *lig. talo-tibiale anterius,* which extends from the front of the inner malleolus to the neck of the astragalus; (*b*) the *lig. talo-tibiale posterius,* stretching between the back of the inner malleolus and the postero-internal rough surface of the astragalus; (*c*) the *lig. tibio-naviculare,* which extends from the tip of the inner malleolus to the inner side of the scaphoid; (*d*) the *lig. calcaneo-tibiale,* which extends between the tip of the inner malleolus and the inner side of the sustentaculum tali; (*e*) the *lig. talo-tibiale profundum,* which consists of deeper fibres extending from the tip of the internal malleolus to the inner side of the astragalus.

Synovial membrane lines the capsular ligament, and, as already described, the joint-cavity communicates directly with the inferior tibio-fibular joint. Both at the front and back of the ankle-joint, as well as superiorly in the angle formed by the three bones, the synovial membrane covers pads of fat.

Movements at the Ankle-Joint.—In the erect attitude the foot is placed at right angles to the leg; in other words, the normal position of the ankle-joint is **flexion.** Those movements which tend to diminish the angle so formed by the dorsum of the foot and the front of the leg, are called **dorsiflexion,** while those which tend to increase the angle, *i.e.* to straighten the foot upon the leg, are called **extension.** As a matter of fact neither dorsiflexion nor extension are ever completely carried out, and the range of movement of which the foot is capable is limited to about 90°. These movements occur about an obliquely transverse axis, as is indicated by the natural outward pointing of the toes. The weight of the body falls slightly anterior to the ankle-joint, so that a certain amount of muscular action is necessitated in order to maintain the foot at right angles to the leg; but additional stability is obtained from the obliquity above mentioned.

When the foot is raised from the ground, muscular action tends naturally to produce a certain amount of extension. When the foot is extended, as in standing on the toes, the hinder narrow part of the astragalus moves forwards into the wider part of the interval between the tibia and

fibula, whereas in dorsiflexion, as in raising the fore part of the foot from the ground, the widest part of the astragalus is forced back between the tibia and fibula; but notwithstanding the difference between these two movements, the fibula remains in close contact with the astragalus by reason of the action of the transverse inferior fibro-fibular ligament and the posterior talo-fibular ligament, so that lateral movement is prevented.

It is doubtful whether lateral movement at the ankle-joint can be obtained by any natural movement of the foot, although it is generally believed that in the position of partial extension a small amount of lateral movement may be produced by the application of external force. "This apparent play" of the ankle-joint during extension "is really due to oscillation of the small bones of the foot on each other, largely of the scaphoid on the astragalus, but also of the cuboid on the calcaneum. Excessive mobility of these latter is restrained by an important function of the posterior tubercle of the cuboid which locks into a notch in the os calcis" (Blake).

INTERTARSAL JOINTS.

These joints (articulationes intertarseæ) are all diarthroses in which the gliding movement is characteristic, as in the carpus. With the view of obtaining a proper conception of the many beautiful mechanical principles involved in the construction of the foot, it is necessary to study these articulations with considerable attention to detail.

Articulatio Talo-calcanea.—The astragalus and os calcis articulate with each other in the articulatio talo-calcanea.

This joint is situated between the inferior facet on the body of the astragalus and a corresponding facet on the upper aspect of the hinder part of the os calcis. On each bone the articulation is limited in front by a wide deep groove which runs obliquely across each bone from within outwards and forwards.

The supporting and investing ligaments form a **capsule**, consisting for the most part of short fibres, but the joint derives additional strength from the external and

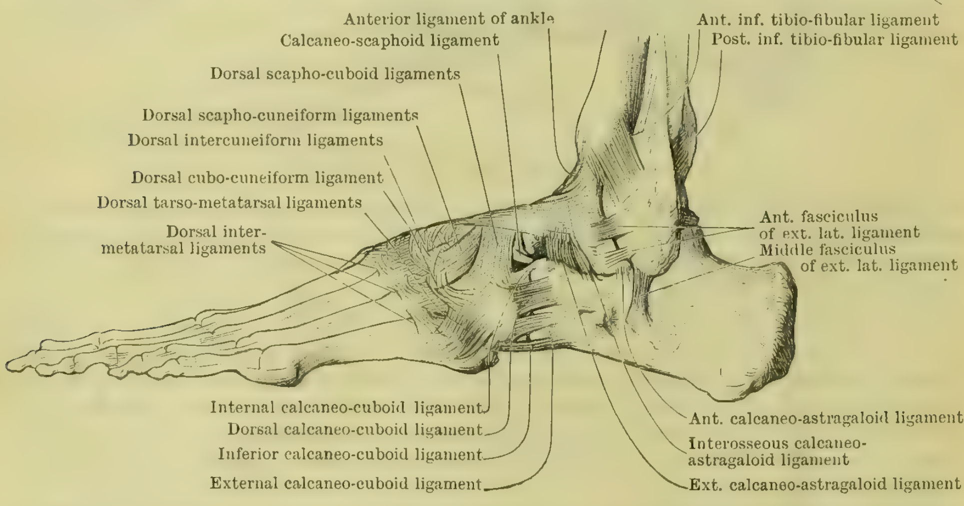


FIG. 229.—LIGAMENTS ON OUTER ASPECT OF ANKLE AND ON DORSUM AND OUTER ASPECTS OF FOOT.

internal lateral ligaments of the ankle-joint. The capsule is subdivided into the following astragalo-calcaneal or talo-calcaneal bands :—

The **anterior talo-calcaneal ligament** (Fig. 229) consists of a band of short fibres placed immediately in relation to the anterior end of the deep groove which bounds the articular facets. They are attached to the antero-external aspect of the neck of the astragalus, from which they extend downwards to the adjacent superior surface of the os calcis.

The **external talo-calcaneal ligament** (Fig. 229) is in continuity with the hinder border of the preceding ligament, and it is placed parallel to, but on a deeper plane than, the middle fasciculus of the external lateral ligament of the ankle-joint. It consists of short fibres passing between the adjacent rough outer margins of the two bones.

The **posterior talo-calcaneal ligament** (Fig. 229) closes the joint cavity on its posterior aspect. It consists of fibres which radiate from the posterior aspect of

the external tubercle of the astragalus to the upper surface of the os calcis, immediately behind the articular facet.

The **internal talo-calcaneal ligament** (Fig. 228) lies obliquely on the inner side of the joint, and consists of fibres which extend from the inner posterior tubercle of the astragalus to the hinder roughened border of the sustentaculum tali. Some of its fibres become continuous with the internal calcaneo-scaphoid ligament.

The **interosseous talo-calcaneal ligament** (Fig. 229) closes the antero-internal aspect of the joint. It is the strongest of the series of ligaments entering into the capsule. Compared with it the other bands are, comparatively speaking, insignificant. Its attachments are to the bottom of each groove, so that it occupies the tarsal canal formed by these opposing grooves.

A **synovial membrane** lines the capsule, and it is distinct from other tarsal synovial membranes.

Articulatio Talo-calcaneo-navicularis.—This is one of the most important of the joints of the foot, not only because the astragalus is here situated in relation to the summit of the antero-posterior arch of the foot, but because the head of the astragalus is received into a composite socket made up of sustentaculum tali, scaphoid, and the inferior or internal calcaneo-scaphoid ligament.

The articular surface on the head of the astragalus presents anteriorly a convex rounded facet for articulation with the scaphoid, inferiorly a convex facet which rests upon the sustentaculum tali, and intermediate between these two there is a triangular facet which articulates with the inferior calcaneo-scaphoid ligament. All these facets are in continuity with each other, and are in front of the tarsal groove on the under surface of the astragalus. Occasionally a fourth narrow facet is found along the outer and hinder part of the articular surface of the head of the astragalus, whereby it articulates with superior or external calcaneo-scaphoid ligament.

The scaphoid or navicular bone presents a shallow, cup-shaped, articular cavity towards the head of the astragalus.

The articular surface of the sustentaculum tali is concave, and is usually marked off into two facets.

Two ligaments play an important part in binding together the os calcis and the scaphoid, although these bones do not directly articulate; and further, these ligaments provide additional articular surfaces for the head of the astragalus. These are the two following :—

(*a*) The **inferior** or **internal calcaneo-scaphoid ligament** (Figs. 228 and 230) is an extremely powerful fibro-cartilaginous tie-band. It extends between the anterior margin of the sustentaculum tali and the inferior surface of the scaphoid bone. Certain of its upper fibres radiate upwards on the inner surface of the scaphoid, and become continuous with the tibio-navicular portion of the deltoid ligament of the ankle-joint. The plantar aspect of this ligament is in contact with the tendon of the tibialis posticus muscle, through which the head of the talus receives great support. Superiorly it contributes an articular surface which forms a triangular portion of the floor of the composite socket in which the head of the talus is received.

(*b*) The **superior** or **external calcaneo-scaphoid ligament** (Fig. 229) lies deeply in the front part of the sinus tarsi, *i.e.* the interval between the astragalus and os calcis. Its fibres are short, and extend from the dorsal surface of the front part of the os calcis, immediately to the outer side of the sustentacular facet, forwards to the outer side of the scaphoid bone. Frequently the ligament presents a surface which articulates with the head of the astragalus, and in these cases it forms a part of the composite socket.

The cavity of the talo-calcaneo-navicular joint is closed posteriorly by the interosseous talo-calcaneal ligament already described. On its inner and outer inferior aspects it is closed by the calcaneo-scaphoid ligaments.

The superior and lateral aspects are covered by an **astragalo-scaphoid membrane or ligament.** This ligament is thin, and extends from the upper non-articular area on the head of the astragalus to the dorsal surface of the scaphoid bone. It may be subdivided into *dorsal* (superior), *lateral* (external), and *medial* (internal). **astragalo-scaphoid ligaments** (Fig. 228), which, with the calcaneo-scaphoid and interosseous talo-calcaneal ligaments, complete the capsular investment of the joint.

A distinct **synovial membrane** lines all parts of the capsule of the joint.

Articulatio Calcaneo-cuboidea.—This is situated between the anterior concavo-convex surface of the os calcis and the posterior similar surface of the cuboid.

The **ligaments** which invest this joint constitute a **calcaneo-cuboid capsule**, whose parts are arranged in relation to the four non-articular sides of the cuboid bone, and are especially strong upon the plantar aspect, in relation to their great importance in resisting strains.

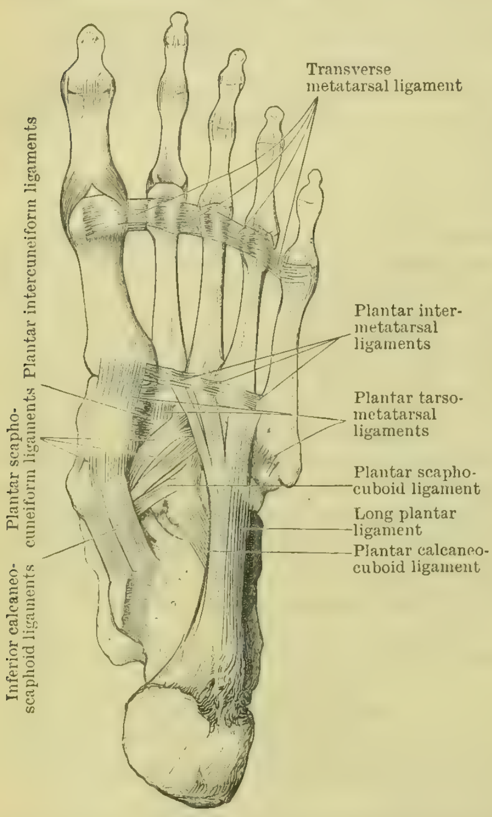


FIG. 230.—LIGAMENTS ON PLANTAR ASPECT OF FOOT.

The **internal calcaneo-cuboid ligament** (Fig. 229) occupies part of the interval between the astragalus and os calcis—sinus tarsi. It is sometimes called the interosseous calcaneo-cuboid ligament, and, in conjunction with the superior or external calcaneo-scaphoid ligament, it forms a V-shaped structure, of which the single end is attached to the os calcis, and the double ends separate to reach contiguous areas on the scaphoid and cuboid respectively.

The **dorsal calcaneo-cuboid ligament** (Fig. 229) is a broad portion of the capsule extending between the dorsal surfaces of the two bones.

The **external calcaneo-cuboid ligament** (Fig. 229) is another but narrower part of the capsule which extends from the outer aspect of the os calcis to the outer side of the cuboid, immediately behind the facet on the tuberosity.

The **inferior calcaneo-cuboid ligaments** are two in number—a superficial and a deep. The superficial series of fibres, the **long plantar ligament** (Fig. 230), is attached to the under surface of the os calcis in front of its tuberosities. It forms a long powerful structure which runs forwards to be fixed to the under surface of the cuboid ridge, but many of its fibres pass superficial to the tendon of the peroneus longus, and extend to the bases of the third, fourth, and fifth metatarsal bones.

The deep series of fibres, the **short plantar ligament** (Fig. 230), is distinctly separated from the former by a layer of areolar tissue. It forms a broad but short band of great strength, which is attached to the under surface of the front end of the os calcis, and extends to the under surface of the cuboid just behind the ridge. Both of these ligaments are of great importance in maintaining the longitudinal arch of the foot, and in this respect are only second to the inferior calcaneo-scaphoid ligaments.

A **synovial membrane** lines the capsule.

Transverse Tarsal Articulation.—This is a term sometimes applied to the astragalo-scaphoid and calcaneo-cuboid joints. These articulations do not communicate with each other; and although there is an occasional direct articulation between the scaphoid and cuboid, it does not constitute an extension of the transverse tarsal joint, but is a prolongation from the series of scapho-cuneiform and cuneo-cuboid articulations.

Nevertheless there is always a set of **ligaments** which bind the scaphoid and cuboid bones together, and these may be regarded as accessory to the various transverse tarsal joints.

The **dorsal scapho-cuboid ligament** (Fig. 229) consists of short oblique fibres which attach the contiguous dorsal surfaces of the cuboid and scaphoid bones.

The **plantar scapho-cuboid ligament** (Fig. 230) is transverse in direction, and extends between adjacent plantar areas of the cuboid and scaphoid bones.

The **interosseous scapho-cuboid ligament** intervenes between contiguous surfaces

of the same bones. When there is an extension of the scapho-cuneiform joint backwards between the scaphoid and cuboid, it is situated in front of the last-mentioned ligament, and is called the **articulatio scapho-cuboidea.** Around this joint the preceding ligaments are grouped. Since, however, the joint is inconstant while the ligaments are always present, it is preferable to consider them as above indicated.

Scapho-cuneiform Articulation (articulatio cuneonavicularis).—This joint is situated between the scaphoid and the three cuneiform bones. The anterior surface of the scaphoid presents facets for each of the cuneiform bones, but its articular surface is not interrupted. These facets form a somewhat convex anterior surface which fits into the shallow articular concavity presented by the proximal ends of the three cuneiform bones. This joint may be extended by the occasional scapho-cuboid articulation already referred to.

The **capsule** is composed of short strong bands which are distinctly visible on all sides except towards the cuboid bone, where the joint may communicate with the cuneo-cuboid and scapho-cuboid joints. Anteriorly the joint communicates with the intercuneiform articulations. The dorsal parts of the capsule are short longitudinal bands termed **dorsal scapho-cuneiform ligaments** (Figs. 228 and 229). These extend without interruption to the inner aspect of the joint. Inferiorly there are similar bands, known as **plantar scapho-cuneiform ligaments** (Fig. 230), also longitudinal in direction, but intimately associated with offsets from the tendon of the tibialis posticus muscle.

The **synovial membrane** which lines the capsule sends prolongations forwards on each side of the middle cuneiform bone, and in addition it often communicates with the cuneo-cuboid joint-cavity, and it always communicates with the scapho-cuboid cavity when that joint exists.

Intercuneiform Articulations.—These are two in number, and exist between adjacent contiguous surfaces of the three cuneiform bones. These surfaces are partly articular and partly non-articular. The small size of the middle cuneiform bone allows the internal cuneiform as well as the external cuneiform to project forwards beyond it on both sides, and therefore the articular surfaces turned towards the middle cuneiform are not entirely occupied by that bone. They form a recess towards the metatarsus, into which the base of the second metatarsal bone is thrust.

Dorsal intercuneiform ligaments (Figs. 228 and 229) constitute fairly strong transverse bands which extend between adjacent dorsal surfaces and invest the joint cavities in this direction.

The plantar or **interosseous intercuneiform ligaments** (Fig. 230) are two strong bands which pass from the rough non-articulur areas on opposite sides of the middle cuneiform to the opposing surfaces of the inner and outer cuneiform bones. These ligaments shut in the joint-cavities inferiorly, and also anteriorly in the case of the outer of the two joints.

The **synovial membrane** is an extension of that which lines the scapho-cuneiform joint; but while it is restricted to the outer of the two joints, in the case of the inner one it is prolonged still further forward to the tarso-metatarsal series of joints.

Cubo-cuneiform Articulation.—This occurs between the rounded or oval facets on the opposing surfaces of the cuboid and external cuneiform.

The **dorsal cubo-cuneiform ligament** (Fig. 229) is a flat, somewhat transverse, band which closes the joint on its superior aspect, and extends between the dorsal surfaces of the two bones.

The **plantar cubo-cuneiform ligament** is difficult to determine. It is situated subjacent to the long plantar ligament, and extends between adjacent rough surfaces of the two bones.

The **interosseous cubo-cuneiform ligament** is the strongest. It closes the joint cavity anteriorly, and is attached to the contiguous non-articular surfaces of the two bones.

The **synovial membrane** is frequently distinct, but at other times the joint cavity communicates with those of the scapho-cuneiform and scapho-cuboid articulations.

Synovial Membranes of the Intertarsal Joints.—Four and sometimes five distinct and separate synovial membranes may thus be enumerated in connexion

with the tarsal articulations, viz.: (1) talo-calcaneal; (2) talo-calcaneo-navicularis; (3) calcaneo-cuboid; (4) scapho-cuneiform and its extensions; (5) occasionally cubo-cuneiform.

TARSO-METATARSAL JOINTS.

The tarso-metatarsal joints are found between certain articular facets on the cuboid and three cuneiform bones on the one hand, and others on the bases of the five metatarsal bones. These articulations are associated with three distinct synovial cavities—namely, an inner, middle, and outer.

(1) The **inner tarso-metatarsal articulation** occurs between the distal convex reniform surface of the internal cuneiform bone and the concavo-reniform surface on the proximal aspect of the base of the first metatarsal bone.

Ligaments which form a **capsule** (Figs. 228 and 230) surround the articulation. In the capsule the **dorsal** and **plantar tarso-metatarsal bands** are its strongest parts, but it is not deficient either on the inner or on the outer aspects.

A separate **synovial membrane** lines the capsule.

(2) The **middle tarso-metatarsal articulation** is an elaborate joint. It involves the three cuneiform bones and the bases of the second, third, and part of the fourth metatarsal bones.

The articulation presents the outline of an indented parapet both on its tarsal and its metatarsal aspects. Thus, on its tarsal side, the inner and the outer cuneiform bones project in front of the middle cuneiform, so that the latter only presents a distal surface to the articulation; while the internal cuneiform presents a portion of its external surface, and the external cuneiform presents both its distal and portions of its outer and inner surfaces, since it projects in front of the cuboid bone. On its metatarsal side the base of the second metatarsal bone fits into the indentation between the outer and inner cuneiforms, to which it presents external and internal articular facets, but its proximal facet rests upon the distal facet of the middle cuneiform. The base of the third metatarsal bone rests its proximal facet upon the outer cuneiform. The fourth metatarsal base presents part of its internal facet to the external side of the outer cuneiform. In this way the indentations alternate on the two sides of the articulation, and an extremely powerful interlocking of parts is provided, which places any marked independent movement of these metatarsal bones entirely out of the question.

The **dorsal tarso-metatarsal ligaments** (Fig. 229) are broad flat bands which represent the most distinct parts of an investing **capsule**. They pass from behind forwards, and while the second metatarsal bone receives three, *i.e.* one from each cuneiform, the third metatarsal only receives one—from the external cuneiform.

The **plantar tarso-metatarsal ligaments** (Fig. 230) correspond with the foregoing in their general arrangement, but they are weaker. That for the second metatarsal is the strongest. Oblique bands extend from the inner cuneiform bone to the second and third metatarsals.

The **interosseous cuneo-metatarsal ligaments** are three in number. The *inner* connects the outer side of the internal cuneiform with the inner side of the base of the second metatarsal bone. The *middle* connects the inner side of the external cuneiform with the outer side of the base of the second metatarsal. The *outer* connects the adjacent outer sides of the external cuneiform and third metatarsal.

The **synovial membrane**, which lines this articulation, sends a prolongation backwards between the inner and middle cuneiform bones, where it opens into the scapho-cuneiform joint. It is likewise prolonged forwards upon both sides of each of the bases of the second and third metatarsal bones.

(3) The **external tarso-metatarsal articulation** is found between the proximal surfaces of the bases of the fourth and fifth metatarsal bones and the distal surface of the cuboid.

The investing **capsule** may be resolved into the following ligaments:—

The **dorsal tarso-metatarsal ligaments** (Fig. 229) resemble those already described. The base of the fourth metatarsal receives one from the external cuneiform and one from the cuboid. The base of the fifth metatarsal receives one from the cuboid.

The **plantar tarso-metatarsal ligaments** (Fig. 230) are the weakest bands of the

series, and consist of scattered fibres passing from the cuboid to the bases of the two metatarsals. Some fibres, which are almost transverse, extend from the external cuneiform to the fifth metatarsal, and additional fibres reach the metatarsals in question from the long plantar ligament (calcaneo-cuboid).

Occasionally the tarsal end of the external interosseous (cuneo-metatarsal) ligament is attached to the inner margin of the cuboid.

The **synovial membrane** is restricted to this articulation, and merely sends a prolongation forwards between the opposing articulate aspects of the fourth and fifth metatarsal bases.

INTERMETATARSAL JOINTS.

The intermetatarsal articulations are found between adjacent lateral aspects of the bases of the four outer metatarsal bones. The articular facets are small, oval, or rounded surfaces which occupy only a limited portion of the flattened contiguous surfaces of the bones. Each joint is provided with a **capsule**, which, however, is not a complete investment, because the three joint cavities are in free communication on their proximal aspects with the tarso-metatarsal joint cavities—one with the outer and two with the middle. The definite fibres of each capsule are situated chiefly in the transverse direction.

The **dorsal ligaments** (Fig. 229) are short bands which extend from one base to the other.

The **plantar** (Fig. 230) and **interosseous ligaments** are similarly arranged, but the latter are the strongest and most important members of this series.

The **synovial membranes** are extensions from those which line the outer and middle tarso-metatarsal joint cavities.

Frequently a bursa is found between the bases of the first and second metatarsal bones. It produces an appearance of indistinct facetting upon these bones, and it may communicate with the inner tarso-metatarsal (cuneo-metatarsal) joint.

The **transverse metatarsal ligament** (Fig. 230) lies upon, and is attached to, the non-articular plantar aspects of the heads of all the metatarsal bones. It differs from the corresponding ligament in the palm in the fact that it binds all the metatarsal bones together, whereas in the palm the thumb is left free. It is closely associated with the plantar fibrous plates of the metatarso-phalangeal joints, to the plantar surfaces of which it contributes prolongations termed ligamenta accessoria plantaria.

METATARSO-PHALANGEAL JOINTS.

Each of these joints is a modified ball-and-socket in which a shallow cup upon the bases of the first phalanges receives the somewhat globular head of a metatarsal bone.

Each joint retains a modified **capsule** (Figs. 228 and 230) which invests the joint. Its only distinct bands are the **ligamenta collateralia**. These are strong cord-like bands which are situated on the inner and outer sides of each joint, where they extend between adjacent rough surfaces.

On the dorsal aspect ligaments distinct from the dorsal expansion of the extensor tendons can hardly be said to exist. The plantar aspect of the capsule consists of a thick **fibrous plate**, which in the case of the great toe presents developed within it two large sesamoid bones. In the other toes this plate remains fibrous throughout, and is grooved on its plantar aspect for the accommodation of the long flexor tendons. It will thus be seen that the metatarso-phalangeal joints are constructed upon a plan very similar to that of the corresponding joints in the hand.

A **synovial membrane** lines the capsule of each articulation.

INTERPHALANGEAL JOINTS.

Each toe possesses two interphalangeal joints except the great toe, which has only one. Not unfrequently in the little toe the distal joint is obliterated through ankylosis. All the joints of this series are uniaxial or hinge joints. The nature of the articular surfaces closely resembles the corresponding joints in the fingers.

Each joint possesses a **capsule** (Figs. 228 and 230) which is either very thin or limited to synovial membrane on the dorsal aspect. The plantar surface of the capsule is strengthened by a **fibrous plate.** The **lateral ligaments** (ligamenta collateralia) are well-defined bands similar to those already described in connexion with the metatarso-phalangeal joints.

A **synovial membrane** lines each capsule in the series.

Mechanism of the foot.—The bones of the foot are arranged in the form of a longitudinal and a transverse arch. The longitudinal arch is built on a very remarkable plan. Posteriorly the mass of the os calcis constitutes a rigid and stable pier of support, while anteriorly, by increasing the number of component parts, the anterior pier acquires great flexibility and elasticity without sacrificing strength or stability. The summit of the arch is formed by the astragalus, which receives the weight of the body from the tibia, and the resilience of the arch is assured by the calcaneo-scaphoid and calcaneo-cuboid ligaments, together with the plantar fascia, which act as powerful braces or tie bands, preventing undue separation of the piers of the arch, and consequent flattening of the foot. The weight of the body is distributed over all the five digits, owing to the arrangement of the bones of the foot in two parallel columns, an **inner** and an **outer.** The former, consisting of the astragalus, scaphoid, and the three cuneiforms, with the three inner metatarsal bones, distributes weight through the talo-scaphoid joint, while the latter (*i.e.* the outer column), comprising the calcaneum, cuboid, and the two outer metatarsal bones, acts in a similar manner through the talo-calcanean joint. The main line of immobility of this arch passes from the heel forwards through the middle toe, but its anterior section, which is slender, is supported on either side by two metatarsal bones, with their proximal tarsal associations, in all of which greater freedom of movement is found. The transverse arch is most marked at the level of tarso-metatarsal articulations. The intersection of these two arches at right angles to each other introduces an architectural feature of great importance in connexion with the support of heavy weights. These longitudinal and transverse arches of the foot are in effect "vaults" intersecting each other at right angles, and in relation to the area which is common to both "vaults" the body weight is superposed exactly as the dome of a cathedral is carried upon two intersecting vaults.

Movements at the Joints of Tarsus, Metatarsus, and Phalanges.—Considered in detail, the amount of movement which takes place between any two of these bones is extremely small, and, so far as the tarsus and metatarsus are concerned, it is mostly of the nature of a gliding motion.

At the metatarso-phalangeal and interphalangeal joints movement is much more free, and is of the nature of **flexion** (bending of the toes towards the sole of the foot, *i.e.* plantar flexion) and **extension.** The latter movement when continued so as to raise the toes from the ground, and bend or approximate them towards the front of the leg, is termed **dorsiflexion.** Coincident with dorsiflexion there is always associated a certain amount of spreading of the toes, which is called **abduction,** and similarly with prolonged flexion there follows a diminution or narrowing of the transverse diameter of the front part of the foot by drawing the toes together—a movement termed **adduction.** In the foot the movements of abduction and adduction take place in regard to a plane which bisects the foot antero-posteriorly through the second toe, for this toe carries the first and second dorsal interosseous muscle.

Notwithstanding the small amount of possible movement in connexion with individual tarsal and metatarsal joints, yet the sum total of these movements is considerable as regards the entire foot. In this way the movements of **inversion** and **eversion** of the foot result. By inversion we mean the raising of the inner border of the foot so that the sole looks inwards, while the toes are depressed towards the ground, and the outer border of the foot remains downwards. This takes place chiefly at the talo-calcanean joint, but the transverse tarsal joints also participate.

Eversion is chiefly the opposite of inversion, and the return of the foot to the normal position of the erect attitude; but under certain conditions it may be carried further, so that the outer border of the foot is raised from the ground, while the inner border is depressed. In both of these movements there is **rotation** between the astragalus and os calcis about an oblique axis which passes from the inner side of the neck of the astragalus to the outer and lower part of the os calcis.

Of course all the movements of the foot are subordinated to its primary functions as an organ of support and progression. For these purposes its longitudinal and transverse arches are of extreme importance. The longitudinal arch resting on the os calcis behind and the heads of the metatarsal bones in front receives the weight of the body, as already explained, on the summit of the astragalus in the line of the third toe. Hence it is that the inner malleolus appears to be unduly prominent on the inner side of the ankle. The transverse arch buttresses the longitudinal one, and therefore, whether the body weight fall to the outer or the inner side of the longitudinal arch, it is supported by a mechanism at once stable, flexible, and elastic, or resilient, and capable of reducing to a minimum all jars that may be received by the forepart of the foot. As the heel is raised, in the act of walking, the weight is gradually transferred from the outer to the inner side of the foot, until the foot finally leaves the ground with a propulsive movement, which results from flexion of the phalanges of the great toe. In this connection it is worthy of note that the longitudinal line of greatest strength is on the inner side of the longitudinal arch, *i.e.* in relation to the great toe.

THE MUSCULAR SYSTEM.

MYOLOGY.

By A. M. Paterson.

The movements of the various parts and organs of the body are brought about by the agency of muscle-cells, characterised by a special histological structure and by the special function of contracting in length under the influence of a proper stimulus. The following section deals solely with the skeletal muscles, the structure, arrangement, and mechanical action of which are based upon a common plan.

The cells of which the skeletal muscles are composed are long, narrow, and characterised by a peculiar striation, which is different from the striation of the muscle-cells of the heart; they also differ both in structure and function from the non-striated (and involuntary) muscle-cells which occur in viscera and vessels.

A typical skeletal muscle consists of a fleshy mass enveloped in a membranous aponeurosis or fascia, and provided at its attached ends or borders with membranous or tendinous connexions to bone, cartilage, or fascia.

Each muscle is made up of a number of **fasciculi** or bundles, arranged together in different ways in different muscles, so as to give rise to the particular form of the muscle in question. These fasciculi are connected together by a delicate connective tissue, the **perimysium externum**, continuous externally with the aponeurosis enclosing the muscle.

Each muscular bundle or fasciculus is composed of a number of narrow, elongated **muscle-cells** or fibres, held together by a still more delicate connective tissue, the **perimysium internum**; this tissue is connected on the one hand with the **sarcolemma** or cell-wall of the muscle-cell, and on the other hand with the coarser tissue of the perimysium externum enclosing the muscular bundles.

By means of these connective tissue envelopes the muscle-cells, the essential agents of motor activity, are brought into firm and intimate relation with the osseous or other attachments of the muscle. Through the agency of sarcolemma, perimysium internum, perimysium externum, aponeurosis, and tendon, the muscle-cell when contracted can produce a precise and definite effect upon the weight to be moved.

Each muscle is supplied by one or more nerves, which, after entering the substance of the muscle, separate into smaller and smaller branches, ultimately forming special terminal end organs in relation to each muscle-cell.

While a muscle may thus be looked upon as an organ endowed with particular properties, and executing a definite movement in response to a stimulus, by the simultaneous contraction of its constituent cells, the various muscles may further be considered in groups, associated by mode of development, nerve-supply, and co-ordination of action. For example, we speak of the hamstring muscles of the thigh, the muscles of the back, and the prævertebral muscles, groups in which separate muscles are associated together by development, nerve-supply, and action. In their development the separate muscles arise from the subdivision of a larger

stratum, as in the limbs, or from the fusion of segmental elements (myotomes), as in the case of the axial muscles; the peripheral nerves supplying skeletal muscles are distributed, through the plexuses or directly, so as to associate particular muscles morphologically and physiologically, and to secure a co-ordinated movement by the simultaneous contraction of several muscles together.

Superficial Fascia.—The superficial fascia is a continuous sheet of areolar tissue which underlies the skin of the whole body. It is closely adherent to the cutis vera, and is sometimes termed **panniculus adiposus**, from the fact that, except beneath the skin of the eyelids, penis, and scrotum, it is always more or less impregnated with fat. It is traversed by the cutaneous vessels and nerves; and its deep surface, membranous in character, is in loose connexion with the subjacent deep fascia.

Deep Fascia. — Underneath the skin and superficial fascia is a fibrous membrane, bluish-white in colour, devoid of fat, and in closest relation to skeleton, ligaments, and muscles. This is the deep fascia. It covers, invests, and in some cases forms the means of attachment of the various muscles. It has a special tendency to become attached to all subcutaneous bony prominences, and to be continuous with the connecting ligaments. It forms septal processes, which separate groups of muscles and individual muscles; enclose glands and viscera; and form sheaths for vessels and nerves. Around joints it gives rise to bands which strengthen the capsule or limit the mobility of the joint, or, as in the case of annular ligaments, bind down the tendons passing over the joint. It not only ensheathes vessels and nerves, but is also perforated by those which pass between superficial and deeper parts.

The term **aponeurosis** is used in relation to muscles. It is synonymous with deep fascia, either as an investing fascia or as a membranous layer which (*e.g.* vertebral aponeurosis) performs at one and the same time the purpose of a deep fascia and the expanded membranous attachment of a muscle.

Bursæ.—Where a tendon passes over a bony surface, or where the superficial fascia and skin cover a bony prominence, there is generally formed a synovial sac, or bursa, containing fluid, for the purpose of lubricating the surface over which the tendon or fascia glides. Allied to these are the synovial sheaths which envelop tendons beneath the annular ligaments in relation to the several joints.

Description of Muscles.—In studying the muscular system it is necessary to note the following characters in reference to each muscle:—(1) The *shape* of the muscle—flat, cylindrical, triangular, rhomboidal, etc.—and the character of its extremities—membranous, tendinous, or fleshy. (2) The *attachments* of the muscle. The *origin* is the more fixed or central attachment: the *insertion* is the more movable or peripheral attachment. (3) The *relations* of the surfaces and borders of the muscle to bones, joints, other muscles, and other important structures. (4) Its *vascular* and *nervous supply;* and (5) *its action.* It must be borne in mind that hardly any single muscle acts alone. Each muscle, as a rule, forms one of a group acting more or less in harmony with, and antagonised by, other and opposite groups.

The muscles of the body are separable histologically into two great divisions, according to the character of the muscle-cells. Striated muscle fibres constitute the whole of the skeletal muscles. Non-striated muscle fibres are characteristic of the muscular system of the viscera and vessels. The heart is composed of a striated muscular structure of a peculiar kind. Only the striated, skeletal muscles are described in this section.

The skeletal muscles may be divided into two series: axial and appendicular. The **axial** muscles comprise the muscles of the trunk, head, and face, including the **panniculus carnosus** (platysma myoides). These muscles are more or less segmental in arrangement, grouped around the axial skeleton. The **appendicular muscles**, the muscles of the limbs, are grouped around the appendicular skeleton. They are not definitely segmental in arrangement, are clearly separate from the axial muscles, and are arranged in definite strata in relation to the bones of the limbs.

THE UPPER LIMB.

FASCIÆ AND MUSCLES OF THE BACK.

FASCIÆ.

The **superficial fascia** of the back presents no peculiarity. It is usually of considerable thickness, and contains a quantity of fat.

The **deep fascia** closely invests the muscles. It is attached in the middle line to the ligamentum nuchæ, supraspinous ligaments, and vertebral spines; laterally it is attached to the spine of the scapula and the clavicle, and is continued over the deltoid region to the arm. In the neck it is attached above to the superior curved line of the occipital bone, and is continuous laterally with the deep cervical fascia. Below the level of the arm it is continuous round the border of the latissimus dorsi muscle, with the fascia of the axilla and of the abdominal wall. In the back and loin it constitutes the **vertebral aponeurosis** or aponeurosis of the latissimus dorsi, concealing the erector spinæ, forming the posterior layer of the **lumbar fascia**, and attached internally to the vertebral spines, externally to the angles of the ribs above, to the lumbar fascia in the loin, and to the iliac crest below.

The Superficial Muscles of the Back.

The posterior muscles connecting the upper limb to the trunk comprise the first two layers of the muscles of the back—(1) trapezius and latissimus dorsi, and (2) levator anguli scapulæ and rhomboidei (major and minor).

The **trapezius** (m. trapezius, cucullaris) is a large triangular muscle. It **arises** from the superior curved line of the occipital bone in its inner third, from the external occipital protuberance, from the ligamentum nuchæ, from the spines of the seventh cervical and all the thoracic vertebræ, and the corresponding supraspinous ligaments. The origin is by direct fleshy attachment, except in relation to the occipital bone, the lowest part of the neck, and the lower thoracic vertebræ, in which places the origins are tendinous. From their origin the muscular fibres converge towards the bones of the shoulder, to be **inserted** continuously from before backwards as follows:—(1) The occipital and upper cervical fibres, into the posterior surface of the clavicle in its outer third; (2) the lower cervical and upper thoracic fibres, into the inner side of the acromion process, and the upper border of the spine of the scapula in its whole length; and (3) the lower thoracic fibres, by a triangular flat tendon, beneath which a bursa is placed, into a rough tuberosity at the base of the spine of the scapula. The occipital portion of the muscle may be in the form of a separate slip, or may be entirely absent.

The trapezius is superficial in its whole extent. Its upper lateral border forms the posterior limit of the posterior triangle of the neck. The lower lateral border, passing over the upper edge of the latissimus dorsi and the vertebral border of the scapula, forms a boundary of the so-called *triangle of auscultation* completed below by the latissimus dorsi, and externally by the vertebral border of the scapula. This space is partly filled up by the rhomboideus major. The deep surface of the muscle is in contact with the levator anguli scapulæ, rhomboidei, latissimus dorsi, and other deeper muscles. The spinal accessory nerve, branches of the cervical plexus (C. 3·4), and of the superficial cervical and posterior scapular arteries, are situated beneath the muscle.

The **latissimus dorsi** is a large triangular muscle with a triple origin. It **arises**—(1) from the vertebral aponeurosis (posterior layer of the lumbar fascia or aponeurosis of the latissimus dorsi). This is a thick membrane which conceals the erector spinæ in the lower part of the back. Through it the latissimus dorsi gains attachment to the spines of the lower six thoracic vertebræ, the spines of the lumbar vertebræ, and the tendon of the erector spinæ with which the aponeurosis blends below. It also arises more externally by fleshy fibres from the posterior part of the iliac crest. From this origin the muscle is directed upwards and out-

wards, its fibres converging to the lower angle of the scapula. In relation to its superior and external borders, additional fibres arise. (2) *Along the outer border* muscular slips arise from the lower three or four ribs, interdigitating with the

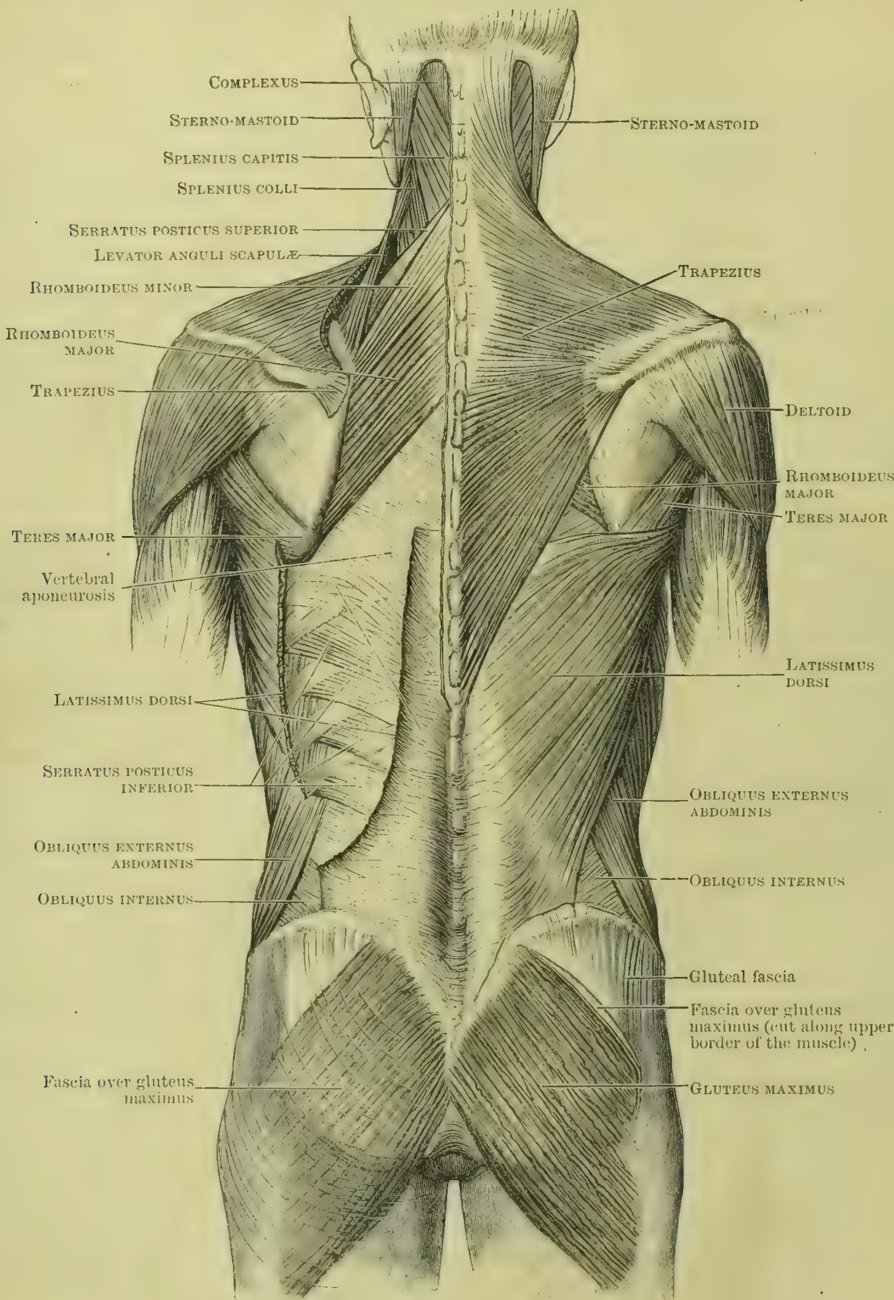


FIG. 231.—SUPERFICIAL MUSCLES OF THE BACK.

origins of the obliquus externus abdominis. (3) As *the upper border* of the muscle passes horizontally over the lower angle of the scapula, an additional fleshy slip usually takes origin from the bone to join the muscle on its deep surface.

Beyond the lower angle of the scapula the latissimus dorsi, greatly narrowed, curves spirally round the teres major muscle, and forms the prominence of the posterior axillary fold. It ends in a ribbon-like tendon, closely adherent at first to the teres major, which is **inserted** into the floor of the bicipital groove of the

humerus, behind the coraco-brachialis and biceps, and the axillary vessels and nerves. It lies in front of the insertion of the teres major, from which it is separated by a bursa.

In the back the latissimus dorsi is superficial, except in its upper part, which is concealed by the trapezius. It lies upon the lumbar fascia, ribs, and lower angle of the scapula, and at its borders two triangular spaces are formed; at the upper border is the so-called *triangle of auscultation:* at the outer border is the *triangle of Petit,* a small space bounded by the iliac crest, the latissimus dorsi, and the obliquus externus abdominis. This is the site of an occasional lumbar hernia.

The **levator anguli scapulæ** (levator scapulæ) is a strap-like muscle, **arising** by tendinous slips from the posterior tubercles of the transverse processes of the first three or four cervical vertebræ, between the attachments of the scalenus medius and splenius colli. It is directed downwards along the side of the neck, to be **inserted** into the vertebral border of the scapula in its upper fourth, from the superior angle to the spine. It is concealed in its upper third by the sternomastoid and deep muscles of the neck. In its middle third it occupies the floor of the posterior triangle. In its lower third it is again hidden from view by the trapezius. It conceals the splenius colli and cervicalis ascendens muscles.

The **rhomboideus minor** may be regarded as a separated slip of the rhomboideus major, with which it is often continuous. It **arises** from the *ligamentum nuchæ* and the spines of the seventh cervical and first thoracic vertebræ. Passing obliquely downwards and outwards, it is **inserted** into the vertebral border of the scapula below the levator anguli scapulæ muscle, and opposite to the base of the spine.

The **rhomboideus major arises** from the spinous processes of the thoracic vertebræ from the second to the fifth inclusive, and from the corresponding supraspinous ligaments. Passing downwards and outwards, it is **inserted** below the rhomboideus minor into the vertebral border of the scapula, between the spine and the lower angle. The muscle is only inserted directly into the scapula by means of its lower fibres. Its upper part is attached to a membranous band, which, connected for the most part by loose areolar tissue to the vertebral border of the scapula, is fixed to the bone at its extremities, above near the base of the spine, and below at the inferior angle.

The rhomboid muscles are concealed for the most part by the trapezius. The lower part of the rhomboideus major is superficial in the *triangle of auscultation.* The muscles cover the serratus posticus superior and the vertebral aponeurosis.

(Chest)

THE FASCIÆ AND MUSCLES OF THE PECTORAL REGION.

FASCIÆ.

The fasciæ and muscles of the chest occupy the space below the clavicle, between the sternum and the humerus, and form at the same time the anterior boundary of the axilla.

The **superficial fascia** of the chest usually contains a quantity of fat, in which the mamma is embedded. The platysma myoides muscle lies beneath its upper part.

The **deep fascia** is attached above to the clavicle, and internally to the sternum. Below it is continuous with the fascia of the abdominal wall. It gives origin to the platysma myoides, and invests the pectoralis major. At the outer border of the great pectoral muscle it is thickened, and forms the floor of the axillary space (**axillary fascia**), continued posteriorly on to the posterior fold of the axilla (teres major and latissimus dorsi), and externally into connexion with the deep fascia of the arm.

Costo-Coracoid Membrane.—Beneath the pectoralis major a deeper stratum of fascia invests the pectoralis minor muscle. At the upper border of this muscle it forms the costo-coracoid membrane, which passes upwards to the lower border of the subclavius muscle, where it splits into two layers, attached in front of and behind that muscle to the borders of the under surface of the clavicle. The membrane traced inwards along the subclavius muscle is attached to the first costal cartilage;

passing outwards along the upper border of the pectoralis minor, it reaches the coracoid process. The part of the membrane extending directly between the first costal cartilage and the coracoid process is thickened and forms the **costo-coracoid ligament.** The costo-coracoid membrane is otherwise thin and of comparatively small importance. It is pierced by the cephalic vein, thoracic axis artery, and branches of the external anterior thoracic nerve. By its deep surface it is connected to the sheath of the axillary vessels.

At the lower border of the pectoralis minor there is a further extension of the deep fascia beneath the pectoralis major. It passes downwards to join the fascia forming the floor of the axilla, and is continued externally into the fascia covering the biceps and coraco-brachialis muscles.

MUSCLES OF THE PECTORAL REGION.

The muscles connecting the upper limb to the axial skeleton anteriorly comprise the pectoralis major, pectoralis minor, subclavius, serratus magnus, and sterno-cleido-mastoid (the last described in a later section).

The **pectoralis major** is a large fan-shaped muscle **arising** in three parts:—(1) *a clavicular portion* arising from the front of the clavicle in its inner half or two-thirds; (2) *a costo-sternal portion,* the largest part of the muscle, arising from the anterior surface of the pre-sternum and meso-sternum by tendinous fibres decussating with those of the opposite muscle: and more deeply from the cartilages of the first six ribs; (3) *an abdominal portion,* a small and separate slip, arising from the aponeurosis of the obliquus externus muscle. The abdominal slip, at first separate, soon merges with the costo-sternal portion, but a distinct interval usually remains between the two first-named parts of the muscle. The fibres converge towards the upper part of the arm, and are **inserted** into (1) the outer border of the bicipital groove of the humerus, extending upwards to the great tuberosity, and blending externally with the insertion of the deltoid, internally with the insertion of the latissimus dorsi; (2) from the upper border of the insertion a membranous band extends upwards to the capsule of the shoulder joint, enveloping at the same time the tendon of the biceps; and (3) from the lower border a band of fascia passes downwards to join the fascia of the arm.

The arrangement of the fibres of the muscle at its insertion is peculiar. The muscle is twisted on itself, so that the lower (*costo-sternal*) fibres are directed upwards and outwards behind the upper (*clavicular*) part of the muscle; in consequence the clavicular part is attached to the humerus lower down than the costo-sternal portion, and is inserted also into the fascia of the arm.

Placed superficially in the chest, the pectoralis major, by its lower or outer border, forms the anterior fold of the axilla. Its upper border is separated from the edge of the deltoid muscle by an interval in which lie the cephalic vein and humeral artery. Its deep surface is in relation with the ribs and intercostal muscles, the costo-coracoid membrane and the structures piercing it, the pectoralis minor, the axillary vessels, and the nerves of the brachial plexus.

Sternalis muscle.—The sternalis muscle is present in 4·4 cases out of 100. It is slightly more frequent in the male than in the female. It has been regarded by different observers as (1) a vestige of the panniculus carnosus, (2) an homologue of the sterno-mastoid, or (3) a displaced slip of the pectoralis major. It is placed, when present, parallel to the sternum upon the sterno-costal origin of the pectoralis major, and has attachments which are very variable, above and below, to the costal cartilages, sternum, rectus sheath, sterno-mastoid, and pectoralis major. Its **nerve supply** is from one or both of the anterior thoracic nerves. In certain rare cases it has been said to be innervated by intercostal nerves.

Chondro-epitrochlearis, dorso-epitrochlearis, axillary arches, costo-coracoideus.—One or other of the above-named slips is occasionally present, crossing the floor of the axilla in the interval between the latissimus dorsi and the pectoralis major. They take **origin** from the costal cartilages, ribs, or borders of the pectoralis major (*chondro-epitrochlearis, axillary arches, costo-coracoideus*), or from the border of the latissimus dorsi (*dorso-epitrochlearis, axillary arches, costo-coracoideus*). Their **insertion** is variable. The *chondro-epitrochlearis* and *dorso-epitrochlearis* are inserted into the fascia of the arm on the inner side, the internal intermuscular septum, or the internal condyle of the humerus. The *axillary arches* are inserted into the border of the pectoralis major, the fascia of the arm, or the coraco-brachialis or biceps muscle. The *costo-coracoideus,* arising from the ribs or the aponeurosis of the obliquus externus, or detaching itself from the

border of the pectoralis major or latissimus dorsi, is attached to the coracoid process, alone or along with one of the muscles attached to that bone. These variable slips of muscle are supplied by the internal anterior thoracic nerve, the lesser internal cutaneous nerve, or the intercosto-humeral.

The **pectoralis minor** is a narrow, flat, triangular muscle. It **arises** from (1) the third, fourth, and fifth ribs near their anterior ends, and (2) from the fascia

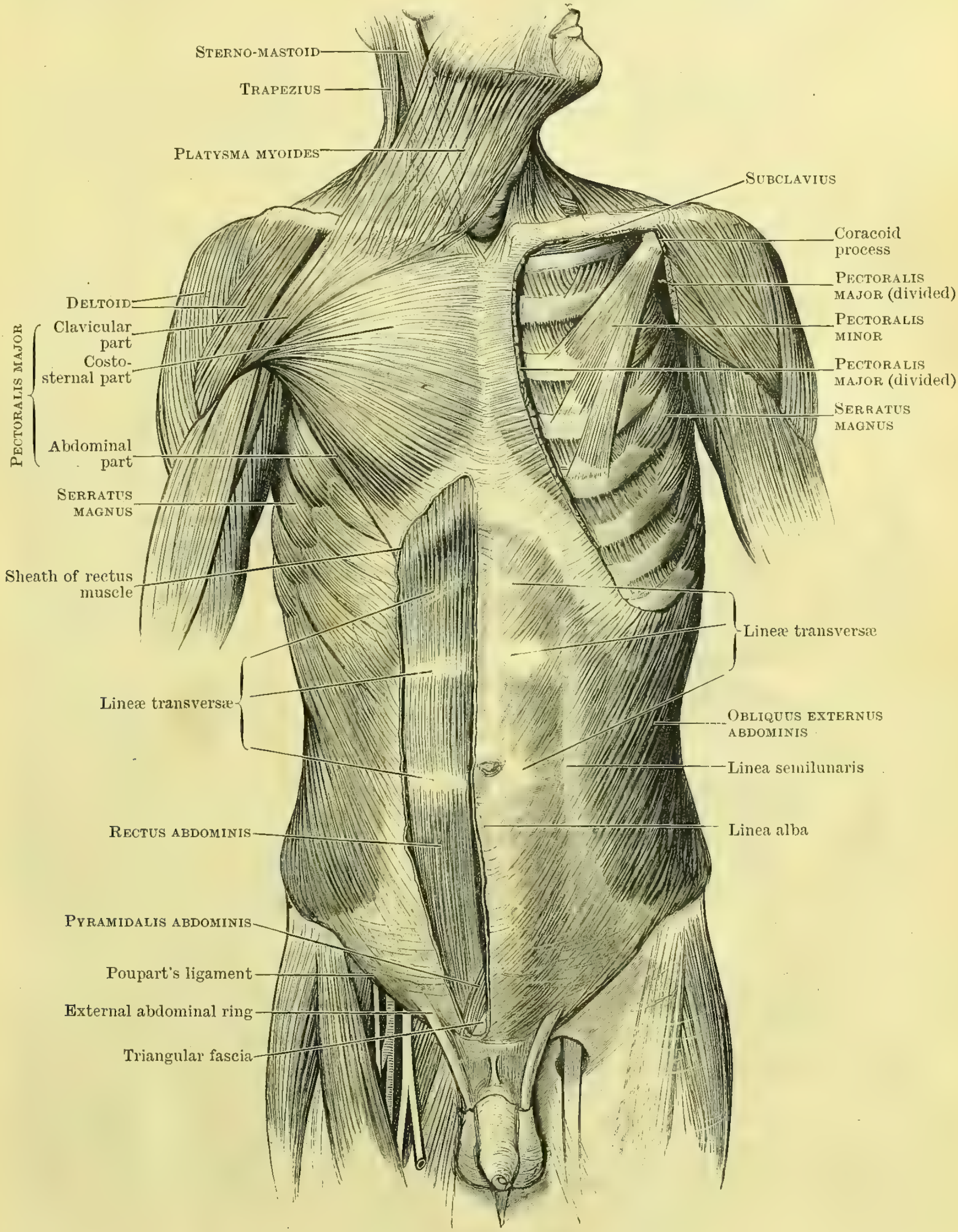


FIG. 232.—ANTERIOR MUSCLES OF THE TRUNK.

covering the third and fourth intercostal spaces between these ribs. Directed obliquely outwards and upwards, it is **inserted** into the front of the extremity of the coracoid process, and usually also into the conjoint origin of the biceps and coraco-brachialis. It is wholly concealed by the pectoralis major, except when the arm is raised, when the outer border of the muscle becomes superficial. It enters into the formation of the front wall of the axilla, and gives attachment along its upper

border to the costo-coracoid membrane. It crosses the axillary vessels and the cords of the brachial plexus, and is pierced by branches of the anterior thoracic nerves.

Either in part or wholly the pectoralis minor may pass over the coracoid process of the scapula, separated from it by a bursa, to be inserted into the coraco-acromial ligament, or the acromion process; or piercing the coraco-acromial ligament, it may be attached to the capsule of the shoulder joint (coraco-humeral ligament).

Pectoralis minimus.—This is a slender slip, rarely present, which extends between the first costal cartilage and the coracoid process.

The **subclavius muscle arises** from the upper surface of the first costal cartilage in front of the costo-clavicular ligament. It is **inserted** into a groove in the middle third of the under surface of the clavicle. The muscle is invested by the fascia which forms the costo-coracoid membrane, and is concealed by the clavicle and the clavicular origin of the pectoralis major.

The **sterno-clavicularis** is a small separate slip, rarely present, extending beneath the pectoralis major from the upper part of the sternum to the clavicle.

The **serratus magnus** (m. serratus anterior) is a large curved quadrilateral muscle occupying the side of the chest and inner wall of the axilla. It **arises** by fleshy slips from the external aspect of the upper eight ribs. The first slip is a double one, arising from the first two ribs and the fascia covering the intervening space. The **insertion** of the muscle is threefold. (1) The first portion of the muscle (from the first and second ribs) is directed backwards to be inserted into the ventral aspect of the upper angle of the scapula. (2) The next three slips of the muscle (from the second, third, and fourth ribs) are inserted into the vertebral border of the scapula. (3) The last four slips (from the fifth, sixth, seventh, and eighth ribs) are directed obliquely upwards and backwards, to be inserted on the ventral aspect of the lower angle of the scapula. The external surface of the muscle is partly superficial below the axilla, on the side wall of the chest, where its slips of origin are seen inter-digitating with those of the obliquus externus abdominis. Higher up it forms the inner wall of the axilla, and is in contact with the pectoral muscles in front and the subscapularis behind. Its upper border appears in the floor of the posterior triangle, and over it the axillary artery and the cords of the brachial plexus pass to reach the armpit. The lower border is oblique, and is in contact with the latissimus dorsi muscle. The deep surface of the muscle is in contact with the chest wall, so that the serratus magnus along with the subscapularis muscle separates the scapula from the ribs. The muscle may extend higher than usual, so as to be continuous with the levator anguli scapulæ.

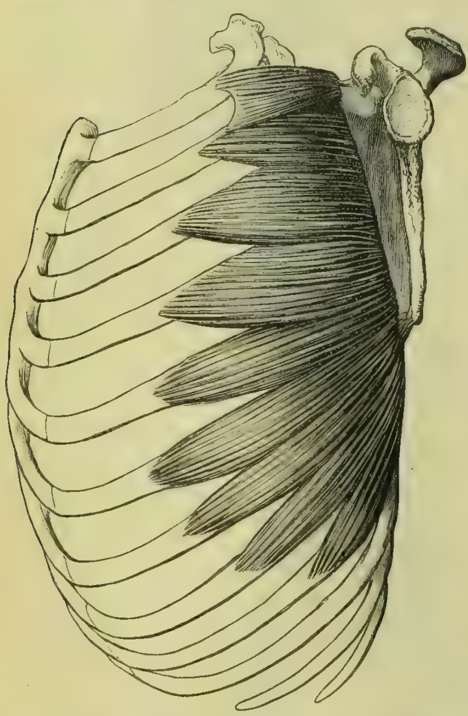


Fig. 233.—The Serratus Magnus Muscle.

Nerve Supply.

The nerves supplying the muscles connecting the upper limb to the trunk are given in the following table :—

Muscles.	Nerves.	Origin.
Trapezius	Spinal accessory nerve Cervical plexus	Spinal Cord C. 3. 4.
Latissimus dorsi	Long subscapular	C. (6.) 7. 8.
Levator scapulæ	Cervical plexus Posterior scapular	C. 3. 4. C. 5.
Rhomboidei	Posterior scapular	C. 5.
Pectorales	External anterior thoracic Internal „ „	C. 5. 6. 7. C. 8. T. 1.
Subclavius	Brachial plexus	C. 5. 6.
Serratus magnus	Posterior thoracic	C. 5. 6. 7.

Actions.

The muscles of this group (together with the sterno-cleido-mastoid and omohyoid muscles) act for the most part in the movements of the shoulder girdle at the sterno-clavicular and acromio-clavicular joints. At the former joint they produce the various movements of the clavicle on the sternum, and cause the shoulder to move in a radius the centre of which is the sterno-clavicular joint. At the latter articulation they produce a rotation of the scapula on the clavicle, and a consequent alteration in the direction of the glenoid fossa. At the same time the several muscles are agents in other equally important movements, when the shoulder girdle is fixed ; movements of the head and neck ; movements of the trunk and ribs ; and, in the case of the pectoralis major and latissimus dorsi, important movements of the arm at the shoulder joint.

1. **Movements of the Shoulder Girdle.**—The action of this group of muscles on the shoulder girdle (mainly corresponding to movements at the sterno-clavicular joint) may be expressed in the following table :—

a. **Movement in a Vertical Plane.**		*b.* **Movement in a Horizontal Plane.**	
Elevation.	**Depression.**	**Forwards.**	**Backwards.**
Trapezius (upper fibres) Levator scapulæ Rhomboidei Sterno-mastoid Omohyoid	Trapezius (lower fibres) Subclavius Pectoralis minor Latissimus dorsi Pectoralis major (lower fibres)	Serratus magnus Pectoralis major Pectoralis minor	Trapezius Rhomboidei Latissimus dorsi
		c. **Rotation**—a combination of these muscles.	

2. **Movements of the scapula on the clavicle** produce an alteration of the direction of the glenoid fossa of the scapula, and are accompanied by movements, inwards and outwards, forwards and backwards, of the inferior angle of the scapula. By the combined action of the muscles acting upon the shoulder girdle a **rotatory movement** of the scapula at the acromio-clavicular joint is effected, by which the relation of the glenoid fossa to the head of the humerus is preserved in movements of the arm.

3. **In forced inspiration,** the sterno-mastoid, trapezius, levator scapulæ, rhomboidei, subclavius, omohyoid, serratus magnus, pectoral muscles, and latissimus dorsi, acting together, raise and fix the shoulder girdle ; while those of them which have costal attachments—subclavius, pectoral muscles, serratus magnus, and latissimus dorsi, simultaneously elevate the ribs and expand the thorax.

4. **Lateral flexion and rotation of the spine** in the neck is effected partly by the action of the trapezius, levator scapulæ, and rhomboid muscles (with the shoulder fixed). The latissimus dorsi and pectoralis major act in climbing in a similar way, raising up the trunk towards the shoulder.

5. **Action on the Upper Limb.**—By reason of their insertion into the humerus the pectoralis major and latissimus dorsi muscles assist the movements of the upper limb. Acting together, the two muscles depress the shoulder, and draw the arm to the side of the body, at the same time rotating the humerus inwards. The two parts of the pectoralis major have slightly different actions on the humerus. The clavicular part of the muscle (portio attollens) draws the arm inwards and upwards ; the costo-sternal part of the muscle (portio deprimens) draws it inwards and

downwards. The latissimus dorsi acting alone, besides rotating the limb, draws it inwards and backwards, as in the act of swimming.

FASCIÆ AND MUSCLES OF THE SHOULDER.

The **deep fascia** covering the scapular muscles presents no feature of special importance. Attached to the clavicle, acromion, and scapular spine, it is thin over the deltoid muscle. Below the deltoid it is thicker; it gives origin to the infraspinatus muscle, and is continuous with the fasciæ of the axilla and the back.

The **muscles** proper to the shoulder comprise the deltoid, supraspinatus, infraspinatus, teres minor, teres major, and subscapularis. They surround, and along with other muscles, act on the shoulder joint.

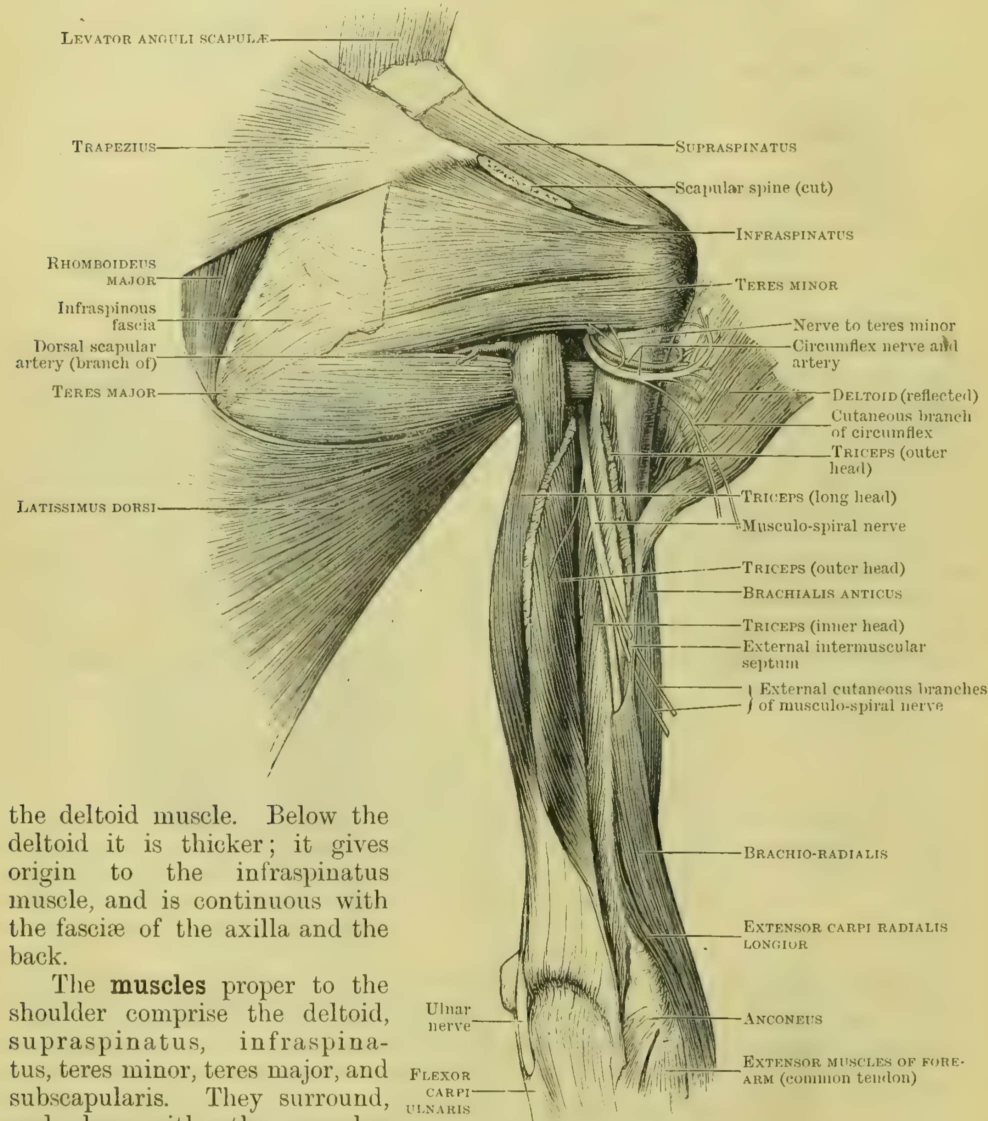


Fig. 234.—Deltoid Region and Back of the Arm.

The **deltoid**, a coarsely fasciculated, multipennate muscle, has an extensive **origin** from (1) the front of the clavicle in its outer third; (2) the outer border of the acromion process; and (3) the lower border of the spine of the scapula. Its origin embraces the insertion of the trapezius. The fibres of the muscle converge to the outer side of the shaft of the humerus, to be **inserted** into a well-marked V-shaped impression above the spiral groove. The insertion is partly united with the tendon of the pectoralis major. The deltoid is superficial in its whole extent, and forms the prominence of the shoulder. Its anterior border is separated from the pectoralis major by a narrow interval, in which the cephalic vein and humeral

artery are placed. The deep surface of the muscle is separated by a bursa from the capsule of the shoulder joint. It is in contact with the *coracoid process,* the coraco-acromial ligament, and the attachments of the pectoralis minor and the

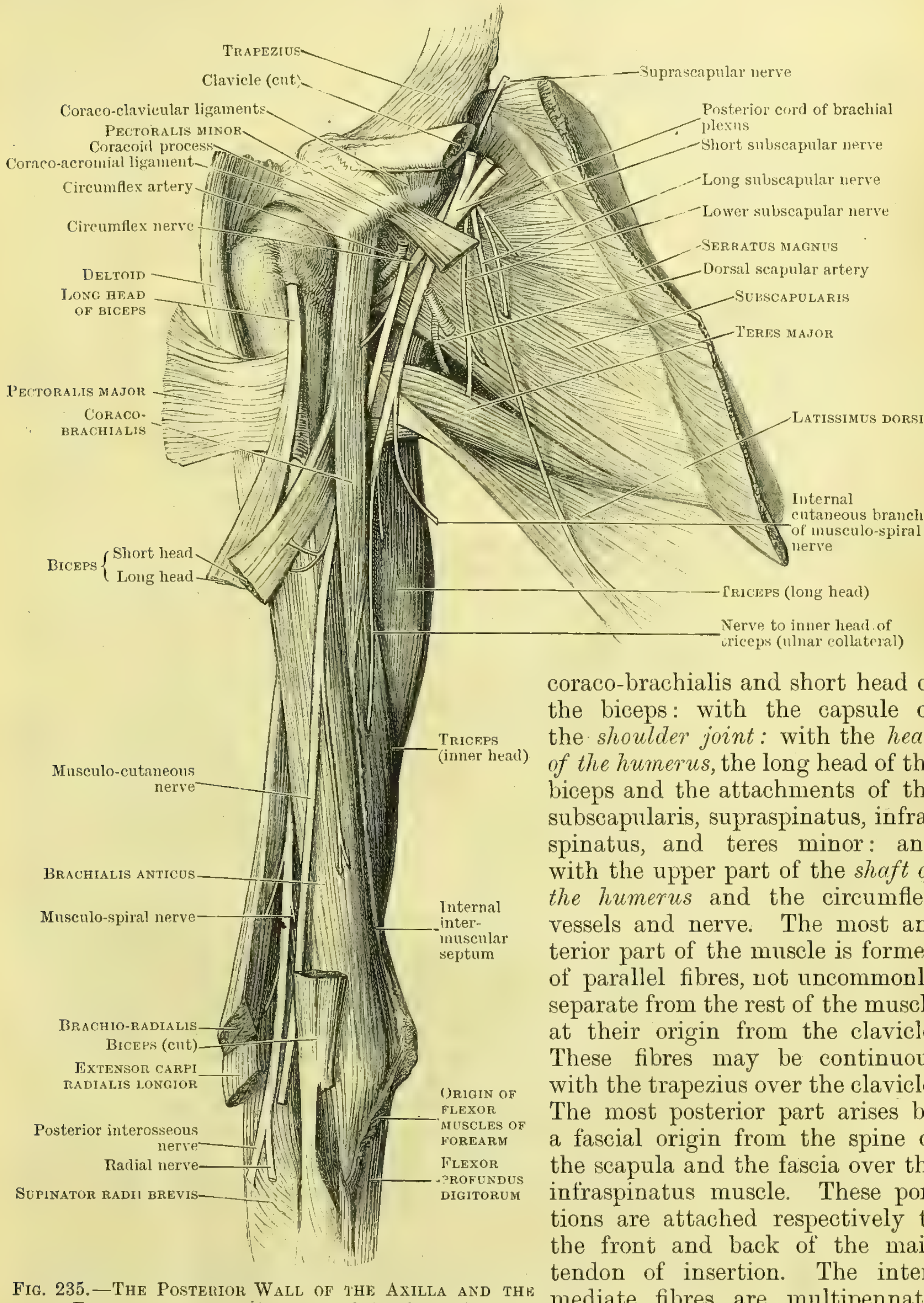


Fig. 235.—The Posterior Wall of the Axilla and the Front of the Arm (the biceps being divided).

coraco-brachialis and short head of the biceps: with the capsule of the *shoulder joint:* with the *head of the humerus,* the long head of the biceps and the attachments of the subscapularis, supraspinatus, infraspinatus, and teres minor: and with the upper part of the *shaft of the humerus* and the circumflex vessels and nerve. The most anterior part of the muscle is formed of parallel fibres, not uncommonly separate from the rest of the muscle at their origin from the clavicle. These fibres may be continuous with the trapezius over the clavicle. The most posterior part arises by a fascial origin from the spine of the scapula and the fascia over the infraspinatus muscle. These portions are attached respectively to the front and back of the main tendon of insertion. The intermediate fibres are multipennate, attached above and below to three or four septal tendons, which extend for a variable distance from the origin and insertion of the muscle.

The **supraspinatus arises** from the supraspinous fossa and the deep fascia over it. It is directed outwards under the acromion process and coraco-acromial ligament, to be **inserted** by a broad thick tendon into the uppermost

facet on the great tuberosity of the humerus, and into the capsule of the shoulder joint.

The muscle is entirely concealed from view by the trapezius, the acromion process, and the deltoid muscle. It covers the neck of the scapula, the suprascapular vessels and nerves, and the upper surface of the capsule of the shoulder joint.

The **infraspinatus** arises from the infraspinous fossa of the scapula (excepting a flat surface along the axillary border) and from the thick fascia over it. The fibres of the muscle converge to the neck of the humerus, separated from it by a bursa, and are **inserted** by tendon into the middle facet on the great tuberosity, and into the capsule of the shoulder joint.

The lower part of the muscle is superficial. The upper part is hidden from view by the deltoid. Along its lower border is the teres minor. Near its insertion it crosses the neck of the scapula and the back of the capsule of the shoulder joint.

The **teres minor** is a small muscle, **arising** from the upper two-thirds of the flat surface on the dorsal aspect of the axillary border of the scapula. Lying alongside the outer border of the infraspinatus, it is **inserted** under cover of the deltoid into the lowest of the three facets on the great tuberosity of the humerus, and into the capsule of the shoulder joint. It is separated from the teres major by the scapular head of the triceps, and by the posterior circumflex vessels and circumflex nerve. Its origin is pierced by the dorsal scapular artery. The muscle is invested by the deep fascia enclosing the infraspinatus, and is sometimes inseparable from that muscle.

The **teres major** is much larger than the preceding muscle. It **arises** from the lower third of the flat surface on the dorsum of the scapula along its axillary border, except for a small area at the lower angle. The muscle is directed along the axillary border of the scapula to the front of the shaft of the humerus, where it is **inserted** into the inner border of the bicipital groove. It is closely adherent just before its insertion to the tendon of the latissimus dorsi muscle.

The teres major is in close relation with the latissimus dorsi muscle, which conceals its origin posteriorly, winds round its outer border, and partially separates its anterior surface from the axillary vessels and nerves. The inner or upper border of the muscle is separated from the subscapularis and teres minor muscles by a quadrilateral interval containing the posterior circumflex vessels and the circumflex nerve, and by a triangular interval containing the dorsal scapular artery. The long head of the triceps passes behind the teres major, and forms the boundary between these two spaces.

The **subscapularis** is a large triangular muscle occupying the venter of the scapula. It **arises** from the whole of the subscapular fossa, except at the angles of the bone. Springing from several ridges in the fossa are septa projecting into the substance of the muscle, which increase the extent of its attachment. Converging to the head of the humerus, the muscular fibres are **inserted** by tendon into the lesser tuberosity and into the capsule of the shoulder joint, under cover of the coracobrachialis and short head of the biceps. This muscle forms the greater part of the posterior wall of the axilla. Its inner or anterior surface is in contact with the serratus magnus and the axillary vessels and nerves. Its deep surface is separated from the neck of the scapula by a bursa. Its upper border passes beneath the coracoid process; its outer border is separated from the teres major by the circumflex vessels and nerve, the triceps muscle, and the dorsal scapular artery.

The **subscapularis minor** is an occasional muscle situated below the capsule of the shoulder joint. It **arises** from the axillary border of the scapula beneath the subscapularis, and is **inserted** into the capsule of the joint or the upper part of the shaft of the humerus.

Nerve Supply.

The muscles of this group are all supplied by the fifth and sixth cervical nerves, through the posterior cords of the brachial plexus.

Muscles.	Nerves.	Origin.
Deltoid, Teres minor	Circumflex	C. 5. 6.
Supraspinatus, Infraspinatus	Suprascapular	
Teres major	Lower subscapular	
Subscapularis	Lower and upper subscapular	

ACTIONS.

The principal action of this group of muscles is on the shoulder joint. They have also secondary actions in relation to movements of the trunk and limbs.

1. Movements at the Shoulder Joint.

a. **Abduction.**	**Adduction.**	*b.* **Flexion** (Forwards).	**Extension** (Backwards).
Deltoid	Teres major	Deltoid (anterior fibres)	Deltoid (posterior fibres)
Supraspinatus	Teres minor	Subscapularis	Teres major
	Pectoralis major	Pectoralis major	Infraspinatus
	Latissimus dorsi	Coraco-brachialis	Latissimus dorsi
	Coraco-brachialis	Biceps	Triceps
	Biceps (short head)		
	Triceps (long head)		
	(Weight of limb)		

c. **Rotation Outwards.**	**Rotation Inwards.**
Deltoid (posterior fibres)	Deltoid (anterior fibres)
Infraspinatus	Teres major
Teres minor	Pectoralis major
	Latissimus dorsi
d. **Circumduction**—combination of previous muscles.	

The various movements at the shoulder joint are greatly aided by the muscles acting on the shoulder girdle. In raising the arm above the head, for instance, the humerus is brought to the horizontal position by the deltoid and supraspinatus, and the movement is continued by the elevators of the shoulder girdle. Again, in forward and backward movements at the shoulder joint, great assistance is derived from muscles acting directly on the shoulder girdle—pectoralis minor and serratus magnus; trapezius and rhomboidei.

2. **In relation to the trunk and limbs,** the shoulder muscles, by fixing the humerus, have auxiliary power on the one hand in movements of the trunk, such as forced inspiration; on the other hand, acting along with muscles fixing the elbow joint, they stiffen the limb so as to permit of the more refined movements of the wrist and fingers.

FASCIÆ AND MUSCLES OF THE ARM.

FASCIÆ.

The **superficial fascia** presents no features of importance. There is a bursa beneath it over the olecranon process, and occasionally another over the inner condyle of the humerus.

The **deep fascia** forms a strong tubular investment for the muscles on the front and back of the humerus. It is continuous above with the deep fascia of the shoulder and axilla, and is further strengthened by fibres derived from the insertions of muscles attached to the upper part of the humerus. At the elbow it becomes continuous with the deep fascia of the forearm, and gains attachment to the condyles of the humerus and the olecranon process of the ulna; it is strengthened also by important bands associated with the insertions of the biceps in front and the triceps behind.

The **intermuscular septa** are processes of the deep fascia attached to the supracondyloid or epicondylic ridges of the humerus. The **internal** and stronger **septum** is placed between the brachialis anticus in front and the inner head of the triceps behind, and gives origin to both. It extends upwards to the insertion of the coraco-brachialis (which is often continuous with it). The **external septum** is thinner and of less extent. It separates the brachialis anticus and brachio-radialis in front from the inner and outer heads of the triceps behind, and gives origin to these muscles. It extends upwards to the insertion of the deltoid, and is pierced by the musculo-spiral nerve and superior profunda artery.

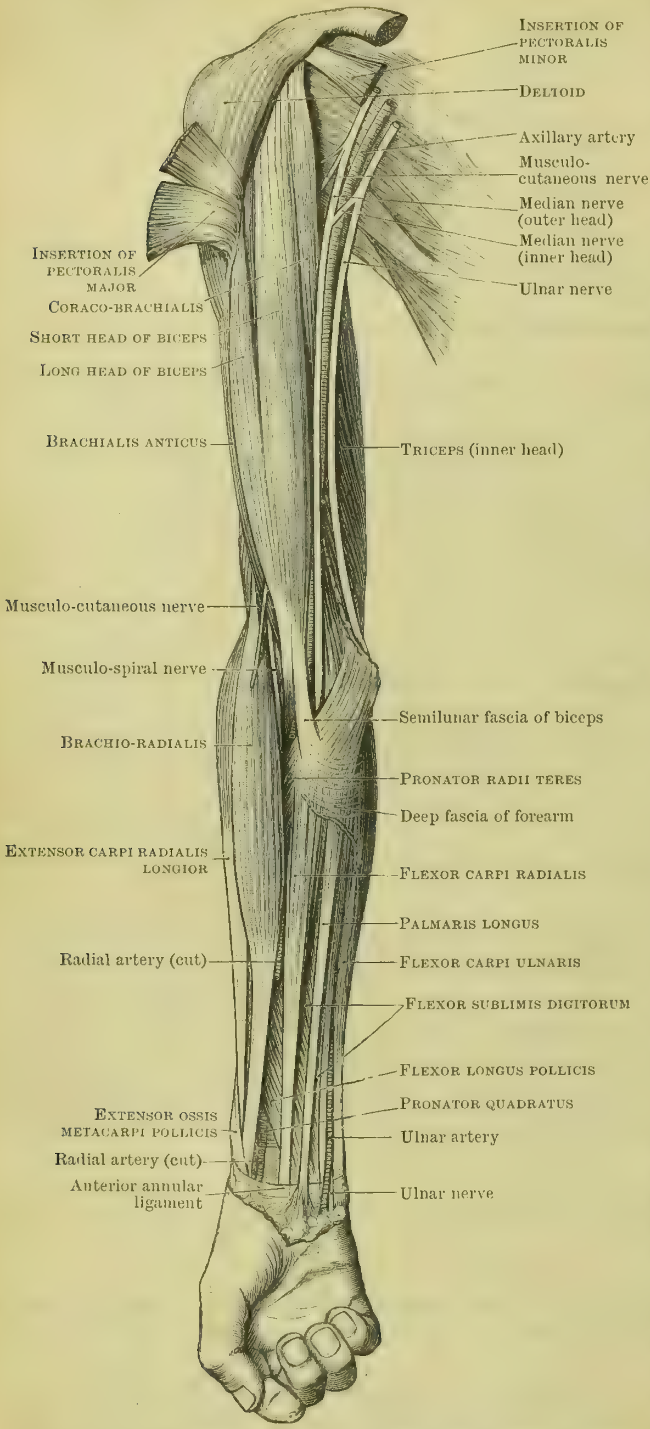


FIG. 236.—SUPERFICIAL MUSCLES ON THE FRONT OF THE ARM AND FOREARM.

MUSCLES.

The **coraco-brachialis** is a rudimentary muscle placed on the front and inner aspect of the arm. It **arises** in common with the short head of the biceps from the tip of the coracoid process of the scapula, and is commonly connected at its origin with the insertion of the pectoralis minor. The muscle is partially subdivided into two parts by the musculo-cutaneous nerve, and ends in a tendon **inserted** into a faint linear impression about an inch in length on the middle of the inner border of the humerus.

The muscle lies on the inner side of the biceps, and is concealed at first by the deltoid and pectoralis major. In the lower part of its extent it is superficial, and forms a swelling beneath the skin on the inner side of the arm which serves as a guide to the axillary and brachial arteries.

The **coraco-brachialis** is the remains of a *threefold muscle*, of which only two elements are usually present in man, but of which in anomalous cases all the parts may be more or less fully developed. The passage of the musculo-cutaneous nerve through the muscle is an indication of

its natural separation into two parts, which represent the persistent middle and inferior elements. The commonest variety is one in which the more superficial (inferior) part of the muscle extends further down the arm than usual, so as to be inserted into the internal intermuscular septum, or even into the internal condyle of the humerus. A third slip (**coraco-brachialis superior** or **brevis, rotator humeri**) may more rarely be present, forming a short muscle **arising** from the root of the coracoid process, and **inserted** into the inner side of the humerus just below the capsule of the shoulder joint.

The **biceps** (m. biceps brachii) is the large superficial muscle which lies on the front of the upper arm. It **arises** by two heads. (1) The **short head** (caput breve) is attached in common with the coraco-brachialis to the tip of the coracoid process of the scapula. This head forms a separate fleshy belly, which is united to the long head by an investment of the deep fascia. (2) The **long head** (caput longum) arises by a round tendon from the supra-glenoid impression at the root of the coracoid process and from the glenoid ligament on either side. Its tendon traverses the cavity of the shoulder joint, and emerging from the capsule (invested by a prolongation of the synovial membrane), it occupies the bicipital groove of the humerus, covered by a fascial prolongation of the tendon of the pectoralis major. In the upper arm it forms a fleshy belly united to that derived from the short head by an envelope of deep fascia.

The **insertion** of the muscle is likewise twofold. (1) The two bellies become connected with a strong *tendon*, attached deeply in the hollow of the elbow to the rough posterior portion of the bicipital tubercle of the radius. A bursa separates the tendon from the anterior portion of the tubercle. (2) From the inner and anterior part of the tendon, and partly in continuity with the fleshy fibres of the muscle, a strong *membranous band* (the **semilunar** or **bicipital fascia**) extends downwards and inwards over the hollow of the elbow to join the deep fascia covering the origins of the flexor and pronator muscles of the forearm.

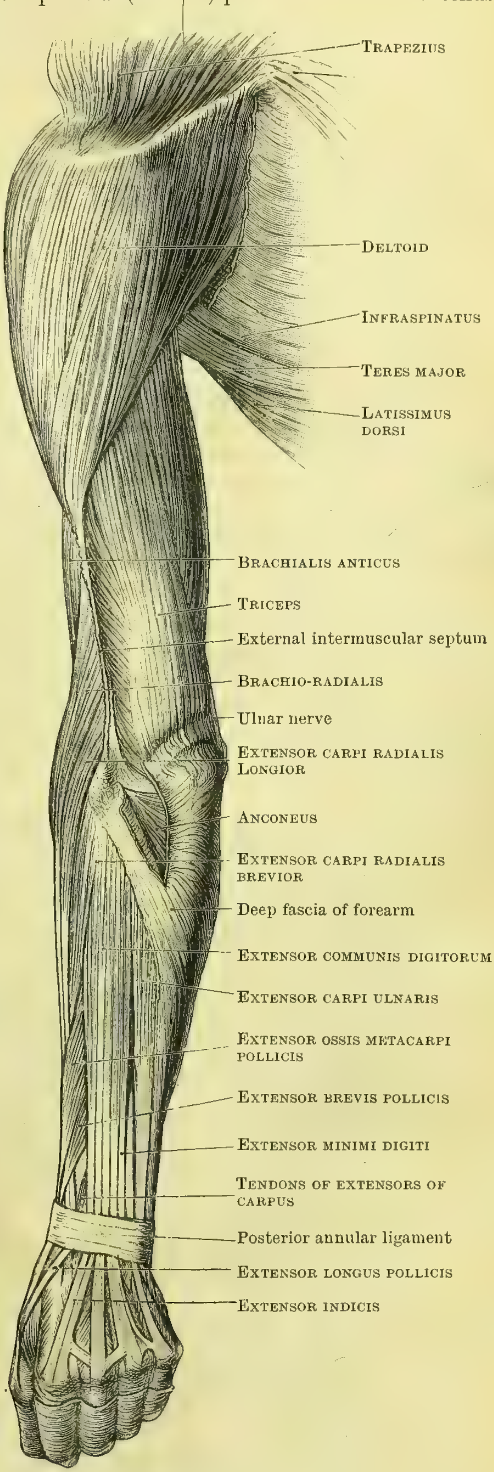


FIG. 237.—THE MUSCLES ON THE BACK OF THE ARM, FOREARM, AND HAND.

Except at its origin and insertion the biceps muscle is placed superficially on the front of the arm, concealing the brachialis anticus and musculo-cutaneous nerve. The brachial artery and median nerve lie along its inner border. The origin of the muscle is deeply placed under cover of the deltoid and pectoralis major. The tendon of insertion in the hollow of the elbow lies beneath the end of the brachial and the beginning of the radial artery.

The **biceps** is an extremely variable muscle. Its chief anomalies are due to an increase or diminution in the number of origins. A **third head of origin** is common (10 per cent), and usually arises from the humerus, between the insertions of the deltoid and coraco-brachialis. Two or even three additional heads may be present at the same time. The long head of the muscle may be absent, or may take origin from the bicipital groove. The muscle may have an additional insertion into the internal condyle of the humerus, or into the fascia of the forearm.

The **brachialis anticus** (m. brachialis) is a large muscle **arising** from the lower two-thirds of the front of the humerus, and from the intermuscular septum on each side. Extending from the insertion of the deltoid above, it ends below in a strong tendon **inserted** into the rough inferior surface of the coronoid process of the ulna. The outer part of the muscle arising from the external epicondylic ridge and external intermuscular septum forms a slip more or less separate, which may be partially fused with the brachio-radialis muscle.

The brachialis anticus is almost wholly concealed from view by the biceps in front, the brachio-radialis externally, and the brachial vessels internally. It covers the elbow joint, and forms part of the floor of the hollow of the elbow.

The **triceps** (m. triceps brachii) is the only muscle on the back of the arm. It **arises** by three heads, an outer and an inner head, from the humerus, and a middle or long head from the scapula. (1) The **middle, long** or **scapular head** (caput longum) begins as a strong tendon attached to the axillary border of the scapula just below the glenoid fossa. This gives rise to a fleshy belly which occupies the middle of the back of the arm. (2) The **outer head** (caput laterale) is attached to the outer border of the humerus from the insertion of the teres minor to the musculo-spiral groove, and to the back of the external intermuscular septum. Its fibres are directed downwards and inwards over the musculo-spiral groove and the inner head of the muscle to the tendon of insertion. (3) The **inner head** (caput mediale) arises by fleshy fibres from a triangular area on the back of the humerus, extending upwards to the insertion of the teres major and downwards to the margin of the olecranon fossa. It also arises on each side from the intermuscular septa.

The three heads of origin are **inserted** by a common tendon, broad and membranous, into the upper end of the olecranon process, and into the deep fascia of the forearm on either side of it. The long and outer heads join the borders of the tendon of insertion, and the inner head is attached to its deep surface.

The long head of the triceps is concealed at first by the teres major and minor, and by the deltoid muscle. Along with the outer head it conceals the musculo-spiral nerve and superior profunda artery, and covers the inner head of the muscle. The inner is the deep head, and is only visible at the lateral borders of the muscle.

The **sub-anconeus** is a small muscle occasionally present, which consists of scattered fibres **arising** from the lower end of the humerus beneath the triceps, and **inserted** into the posterior ligament of the elbow joint.

Nerve Supply.

The following nerves supply the muscles of the arm :—

Muscles.	Nerves.	Origin.
Coraco-brachialis Biceps Brachialis anticus	Musculo-cutaneous	C. 7. C. 5. 6. C. 5. 6.
Brachialis anticus Triceps Outer head Middle and inner heads	Musculo-spiral	C. (5) 6. C. (6) 7. 8. C. 7. 8.

Actions.

(1) The chief action of these muscles is on the elbow joint, producing along with other muscles flexion and extension. The flexor muscles are much more powerful than the extensors.

Table of Muscles acting on the Elbow Joint.

Flexors.	Extensors.
Biceps Brachialis anticus Brachio-radialis Pronator radii teres Flexors of wrist and fingers Extensors of wrist (in pronation)	Triceps Anconeus Extensors of wrist and fingers (in supination)

(2) **Subordinate** and **accessory movements** are performed by all the muscles of this group except the brachialis anticus. The **biceps** supinates the forearm, flexes the elbow, and with the aid of the **coraco-brachialis** adducts and flexes the humerus at the shoulder joint. The **triceps** through its scapular head adducts and extends the humerus, besides extending the elbow joint.

FASCIÆ AND MUSCLES OF THE FOREARM AND HAND.

FASCIÆ.

The **superficial fascia** in the forearm presents no exceptional features. On the dorsum of the hand it is loose and thin; in the palm it is generally well furnished with fat, forming pads for the protection of the vessels and nerves. It is closely adherent to the palmar fascia, and to the skin, especially along the lines of flexure.

The **palmaris brevis** is a quadrilateral subcutaneous muscle occupying the inner side of the hand under the superficial fascia. It **arises** from the inner border of the thick central portion of the palmar fascia, and is **inserted** into the skin of the inner border of the hand for a variable distance. It covers the ulnar artery and nerve, branches of which supply it. Its action is to wrinkle the skin of the inner border of the hand, and by raising up the skin and superficial fascia, to deepen the hollow of the hand.

The **deep fascia** of the forearm and hand is continuous above with the deep fascia of the arm. At the upper part of the forearm it is strengthened by additional fibres around the elbow; in front by fibres from the semilunar fascia of the biceps, behind by the fascial insertions of the triceps, and laterally by fibres derived from the humeral condyles in relation to the common tendons of origin of the flexor and extensor muscles of the forearm. It closely invests and gives origin to these muscles. It is attached to the posterior border of the ulna in the whole length of the forearm, and affords increased

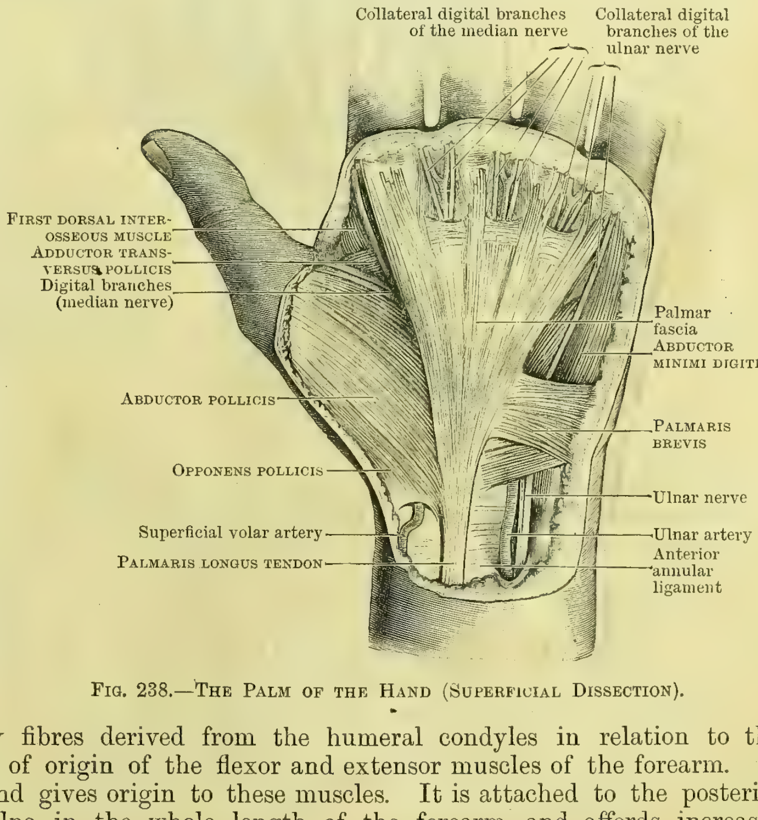


Fig. 238.—The Palm of the Hand (Superficial Dissection).

attachment to the flexor and extensor carpi ulnaris and the flexor profundus digitorum. Above the wrist the fascia is pierced anteriorly by the tendon of the palmaris longus and by the ulnar artery and nerve. At the wrist it gains attachment to the bones of the forearm and carpus, is greatly strengthened by addition of transverse fibres, and constitutes **the annular ligaments.**

The **anterior annular ligament** of the wrist is a band about an inch and a half in depth, continuous above and below with the deep fascia of the forearm and hand. It is attached to the scaphoid and trapezium externally; to the pisiform and unciform bones internally; and it forms a membranous arch binding down in the hollow of the carpus the flexor tendons of the wrist, and the median nerve. It is divided into *two compartments,* the larger accommodating the tendons of the

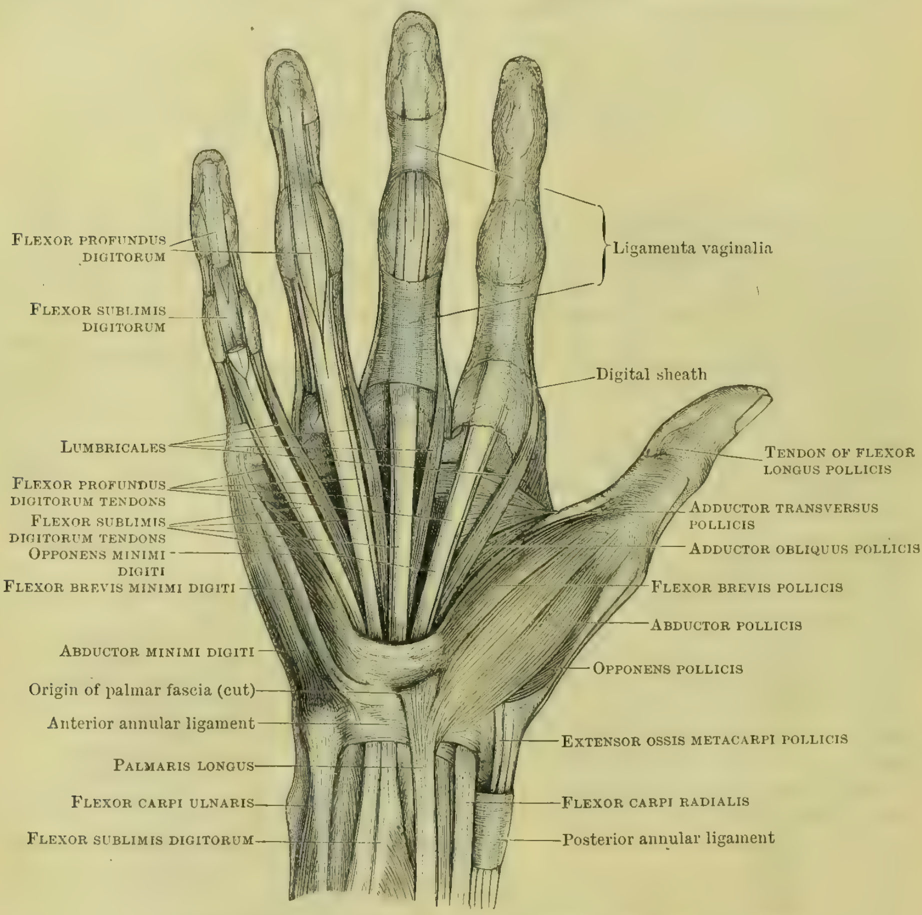


Fig. 239.—The Muscles and Tendons in the Palm of the Hand.

flexors of the digits and the median nerve, the smaller (placed externally) containing the tendon of the flexor carpi radialis. There are *three synovial membranes* in these compartments: one for the flexor carpi radialis tendon, the other two, which may communicate together, enveloping the tendons of the flexor longus pollicis and the flexor tendons of the fingers respectively. The surface of the ligament is crossed by the palmar branches of the median and ulnar nerves; by the tendon of the palmaris longus muscle, which is attached to its surface; and by the ulnar artery and nerve, which are again bridged over and protected by a band of fibrous tissue passing from the pisiform bone and the superficial fascia to the surface of the ligament. To the lower border of the ligament are attached the palmar fascia in the centre, and the superficial muscles of the thumb and the muscles of the little finger on each side.

The **posterior annular ligament** of the wrist is placed at a higher level

than the previous ligament. It consists of an oblique band of fibres about an inch broad, attached externally to the outer side of the lower end of the radius, and internally to the lower end of the ulna, the carpus, and the internal lateral ligament of the wrist. It is covered by veins, by the radial nerve, and by the dorsal branch of the ulnar nerve. *Six compartments* are formed beneath it by the attachment of septal bands to the radius and ulna. Each compartment is provided with a *synovial membrane*, and they serve to transmit the extensor tendons of the wrist and fingers in the following order from without inwards:—

1. Extensor ossis metacarpi pollicis and extensor brevis pollicis.
2. Extensores carpi radiales, longior and brevior.
3. Extensor longus pollicis.
4. Extensor communis digitorum and extensor indicis.
5. Extensor minimi digiti.
6. Extensor carpi ulnaris.

The thin deep fascia of the dorsum of the hand is lost over the expansions of the extensor tendons on the fingers. Beween the metacarpal bones a strong layer of fascia covers and gives attachment to the interossei muscles.

The **palmar fascia** is of considerable importance. In the centre of the palm it forms a thick triangular membrane, the apex of which joins the lower edge of the anterior annular ligament, and receives the insertion of the tendon of the palmaris longus muscle. The fascia separates below into four slips, one for each finger, connected together by transverse fibres, forming beneath the webs of the fingers the **superficial transverse metacarpal ligament.** Beyond this each slip separates into two parts, to be connected to the sides of the metacarpo-phalangeal joints and the first phalanx of the inner four digits. In the cleft between the two halves of each slip the **digital sheath** is attached and extends downwards on to the finger. The lateral borders of this triangular central portion of the palmar fascia are continuous with thin layers of deep fascia, which cover and envelop the muscles of the thenar and hypothenar eminences. The inner border gives origin to the *palmaris brevis muscle.*

The **digital sheaths** are tubular envelopes extending along the anterior aspect of the digits and enclosing the flexor tendons. Each consists of a continuous fibrous sheath attached to the lateral borders of the phalanges and interphalangeal joints, and continuous above with the palmar fascia. Opposite each interphalangeal articulation the digital sheath is loose and thin ; opposite the first two phalanges (the first only in the case of the thumb) it becomes extremely thick, and gives rise to the **ligamentum vaginale**, which serves to keep the tendons closely applied to the bones during flexion of the fingers. Within each digital sheath are the flexor tendons, enveloped in a synovial membrane which not only envelops the tendon but also lines the interior of the sheath. The synovial membranes of the digital sheaths extend a short distance upwards in the palm, and in some cases communicate with the large synovial membranes lining the flexor tendons beneath the annular ligament. There may be a separate distinct synovial membrane for each digit ; but most commonly only the sheaths for the three middle digits have separate synovial membranes ; those for the flexor longus pollicis and for the flexor tendons of the little finger communicate usually with the synovial membranes placed beneath the anterior annular ligament.

THE MUSCLES ON THE FRONT AND INNER ASPECT OF THE FOREARM.

The pronator and flexor muscles which lie on the front of the forearm occupy different levels, and are divisible into two main groups, **superficial** and **deep.**

Superficial Muscles.

The **superficial muscles** form the prominence on the front and inner side of the forearm, and all take origin in whole or part by means of a common tendon from the internal condyle of the humerus. The group comprises five muscles—

pronator radii teres, flexor carpi radialis, palmaris longus, flexor carpi ulnaris, and flexor sublimis digitorum.

The **pronator radii teres** (m. pronator teres) is the most external and shortest muscle of this group. It has a double **origin**: (1) a *superficial head*, the main origin, from the common tendon from the internal condyle of the humerus, from the fascia over it, and from an intermuscular septum between it and the flexor carpi radialis; (2) a *deep head*, a slender slip from the inner side of the coronoid process of the ulna, which joins the superficial origin of the muscle on its deep surface. The median nerve separates the two heads from one another. The muscle is directed downwards and outwards to be **inserted** into an oval impression on the middle of the outer surface of the radius.

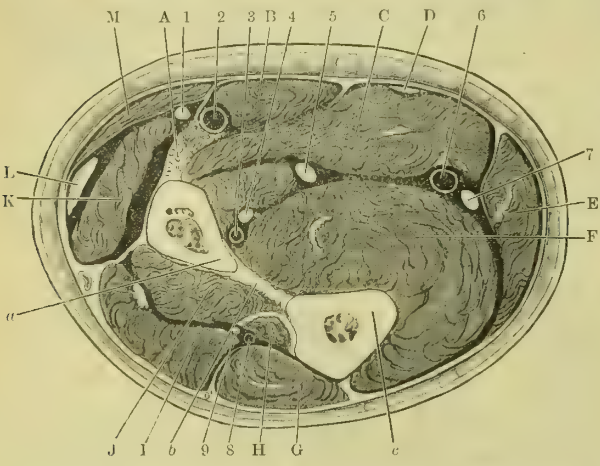


Fig. 240.—Section across the Forearm in the Middle Third.

A, Pronator radii teres (insertion); B, Flexor carpi radialis; C, Flexor sublimis digitorum; D, Palmaris longus; E, Flexor carpi ulnaris; F, Flexor profundus digitorum; G, Extensor carpi ulnaris; H, Extensor longus pollicis; I, Extensor communis digitorum; J, Extensor ossis metacarpi pollicis; K, Extensor carpi radialis brevior; L, Extensor carpi radialis longior; M, Brachio-radialis. *a*, Radius; *b*, Interosseous membrane; *c*, Ulna. 1, Radial nerve; 2, Radial Artery; 3, Anterior interosseous artery; 4, Anterior interosseous nerve (underneath flexor longus pollicis); 5, Median nerve; 6, Ulnar artery; 7, Ulnar nerve; 8, Posterior interosseous artery; 9, Posterior interôsseous nerve.

The muscle forms the inner boundary of the hollow of the elbow. It is superficially placed, except near its insertion, where it is covered by the brachio-radialis muscle and by the radial vessels and nerve. The flexor carpi radialis is on its inner side. The muscle conceals the ulnar and radial origins of the flexor sublimis digitorum, and the median nerve and ulnar artery, which are separated from one another by the deep head of origin.

The **flexor carpi radialis** muscle has a single **origin** from the common tendon from the internal condyle, from the fascia over it, and from the intermuscular septa on either side. Its fleshy belly gives place to a strong round tendon in the lower half of the forearm, which, at the wrist, enters the hand in a special compartment beneath the anterior annular ligament, and after occupying the groove on the trapezium, is **inserted** into the upper ends of the second and third metacarpal bones on their anterior surfaces.

The flexor carpi radialis is superficial except near its insertion. Its fleshy belly in the upper half of the arm lies between the pronator radii teres and the palmaris longus, and conceals the flexor sublimis digitorum. Its tendon in the lower half of the arm can be felt beneath the skin, on the outer side of the palmaris longus tendon. It is an important guide to the radial vessels which are placed in the hollow external to it. After passing beneath the anterior annular ligament the tendon is concealed by the origins of the short muscles of the thumb. Besides the synovial bursa enveloping the tendon beneath the annular ligament, another is found beneath the tendons of insertion into the metacarpus.

The **palmaris longus** **arises** also by a single head of origin from the common flexor tendon from the internal condyle, from the fascia over it, and from intermuscular septa on either side. It forms a short fusiform muscle, which ends in the middle of the forearm in a long flat tendon. This pierces the deep fascia above the wrist, and passing over the anterior annular ligament, is **inserted** (1) into the surface of the anterior annular ligament, and (2) into the apex of the thick central portion of the palmar fascia.

The palmaris longus is the smallest muscle of the forearm. It is placed between

the flexor carpi radialis and the flexor carpi ulnaris, and covers the flexor sublimis digitorum. In the lower third of the forearm its tendon is placed directly over the median nerve, along the outer border of the tendons of the flexor sublimis digitorum.

The palmaris longus is the most variable muscle in the body, and is often absent (10 per cent).

The **flexor carpi ulnaris** muscle has a double **origin**, from the humerus and from the ulna. (1) It arises from the common tendon attached to the condyle of the humerus, the fascia over it, and an intermuscular septum externally. (2) By means of the deep fascia of the forearm it obtains an attachment to the olecranon process and the posterior border of the ulna in its upper three-fifths. The fleshy fibres join a tendon which lies on the anterior border of the muscle and is **inserted** into the pisiform bone.

The muscle is superficially placed along the inner border of the forearm. It lies internal to the palmaris longus and flexor sublimis digitorum, and conceals the flexor profundus digitorum. The ulnar nerve (which enters the forearm between the two heads of origin of the muscle) is concealed by it in its whole length. The ulnar artery lies under cover of the muscle in its lower two-thirds. The tendon of the muscle serves as a guide to the artery in the lower half of the forearm.

The **flexor sublimis digitorum** occupies a deeper plane than the four previous muscles. It has a threefold **origin**, from the humerus, radius, and ulna. (1) The chief or *humeral* origin is from the internal condyle of the humerus by the common tendon, from the internal lateral ligament of the elbow, and from adjacent intermuscular septa. (2) The *ulnar* origin is by a slender fasciculus from the inner border of the coronoid process of the ulna, above the origin of the pronator radii teres.

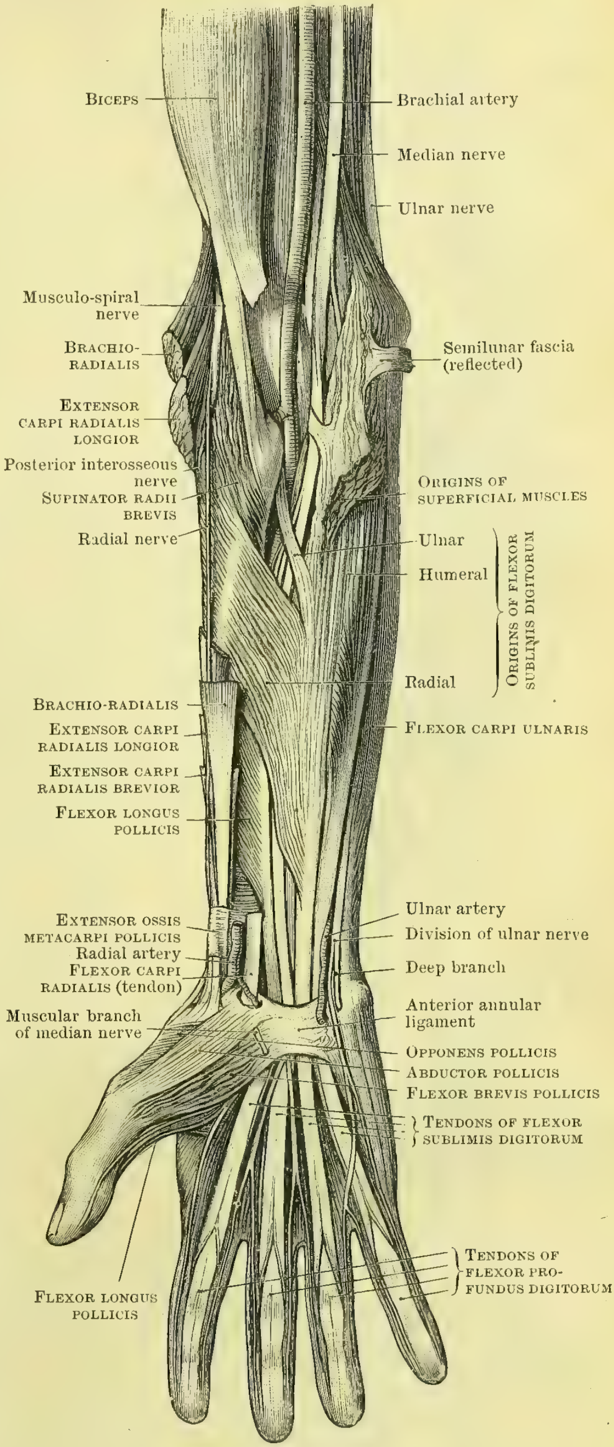


FIG. 241.—THE MUSCLES AND NERVES ON THE FRONT OF THE FOREARM AND HAND.

The pronator radii teres, flexor carpi radialis, and palmaris longus have been removed.

(3) The *radial* origin is from the oblique line and middle third of the outer border of the radius by a thin fibro-muscular attachment.

The muscle separates in the lower third of the forearm into four parts, each provided with a separate tendon which passes beneath the anterior annular ligament, crosses the palm of the hand, and enters the corresponding digital sheath. Within the digital sheath each tendon is split into two parts by the tendon of the flexor profundus digitorum; after surrounding that tendon the two parts are partially reunited on its deep surface, and are **inserted**, after partial decussation, in two portions into the sides of the second phalanx.

The **vincula accessoria** form additional insertions of the muscle. They consist of the **ligamenta longa** and **brevia**. The ligamentum breve is a triangular band of fibres occupying the interval between the tendon and the digit for a short distance close to the insertion. It is attached to the front of the inter-phalangeal articulation and the head of the first phalanx. The ligamentum longum is a long narrow band extending from the back of the tendon to the upper part of the anterior surface of the first phalanx.

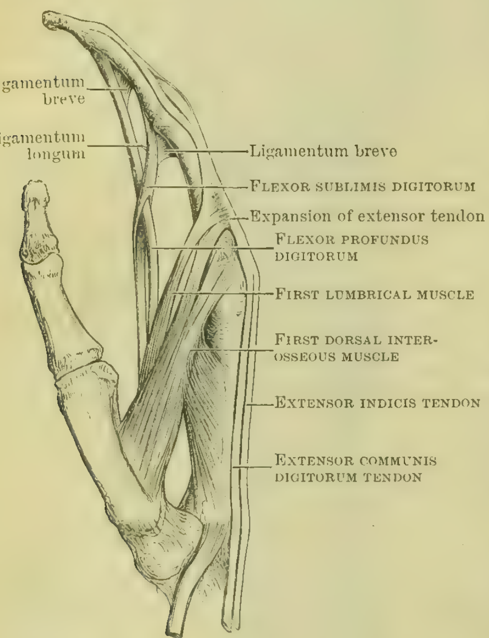


Fig. 242.—The Tendons attached to the Index Finger.

The flexor sublimis digitorum muscle is partially concealed in the forearm by the other more superficial muscles of this group, and by the radial vessels and nerve. It conceals the deeper muscles of the forearm, the median nerve, and the ulnar artery. Its inner border is in contact with the flexor carpi ulnaris, and in the lower half of the forearm with the ulnar vessels and nerve. The median nerve emerges at its outer border above the wrist, and separates the muscle from the tendon of the flexor carpi radialis. At the wrist the four tendons are arranged in pairs, those for the middle and ring fingers in front, those for the fore and little fingers behind, and are enveloped in a synovial sheath along with the tendons of the flexor profundus digitorum beneath the anterior annular ligament. In the palm the tendons separate, and lying beneath the superficial palmar arch, conceal the tendons of the deep flexor and the lumbrical muscles. Within the digital sheaths on the fingers the tendons at first conceal those of the deep flexor; after being pierced by them, they are in turn concealed by these tendons at their insertion.

Deep Muscles.

The **deep muscles** on the front of the forearm are three in number: flexor profundus digitorum, flexor longus pollicis, and pronator quadratus.

The **flexor profundus digitorum** is a large muscle **arising** from the ulna, the interosseous membrane, and the deep fascia of the forearm. Its ulnar origin is from the anterior and inner surfaces of the bone, extending up so as to include the inner side of the olecranon process, and embrace the insertion of the brachialis anticus into the coronoid process. It arises external to the ulna from the inner half of the interosseous membrane in its middle third, and internally from the deep fascia of the forearm behind the origin of the flexor carpi ulnaris.

The muscle forms a broad thick tendon which passes beneath the anterior annular ligament, and divides in the palm into four tendons for **insertion** into the terminal phalanges of the fingers. The tendon associated with the fore finger is usually separate from the rest of the tendons in its whole length. Each tendon enters

a digital sheath beneath the tendon of the flexor sublimis digitorum, which it pierces opposite the first phalanx, and is finally inserted into the base of the terminal phalanx. Like the tendons of the flexor sublimis, those of the deep flexor are provided with vincula accessoria, viz. **ligamenta brevia** attached to the capsule of the second interphalangeal articulation, and **ligamenta longa**, which are in this case connected to the tendons of the subjacent flexor sublimis digitorum.

Lumbricales. — Four small cylindrical muscles are associated with the tendons of the flexor profundus digitorum in the palm of the hand. *The two outermost muscles* **arise** from the radial side of the tendons of the flexor profundus digitorum destined for the fore and middle fingers. *The two innermost muscles* **arise**, each by two heads, from the adjacent sides of the second and third, and third and fourth tendons. From these origins the muscles are directed downwards to the radial side of each of the metacarpo-phalangeal joints, to be **inserted** into the capsules of these articulations, the outer border of the first phalanx, and chiefly into the outer side of the extensor tendon on the dorsum of the phalanx. The lumbricales vary considerably in number, and may be increased to six or diminished to two.

In the forearm the flexor profundus digitorum is concealed by the flexor sublimis digitorum and flexor carpi ulnaris muscles, and by the ulnar nerve and artery. Under the anterior annular ligament the muscle is placed beneath the tendons of the flexor sublimis digitorum, and is enveloped in the common bursal sac. In the palm the tendons, along with the lumbrical muscles, cover the deep palmar arch and the interossei muscles, and

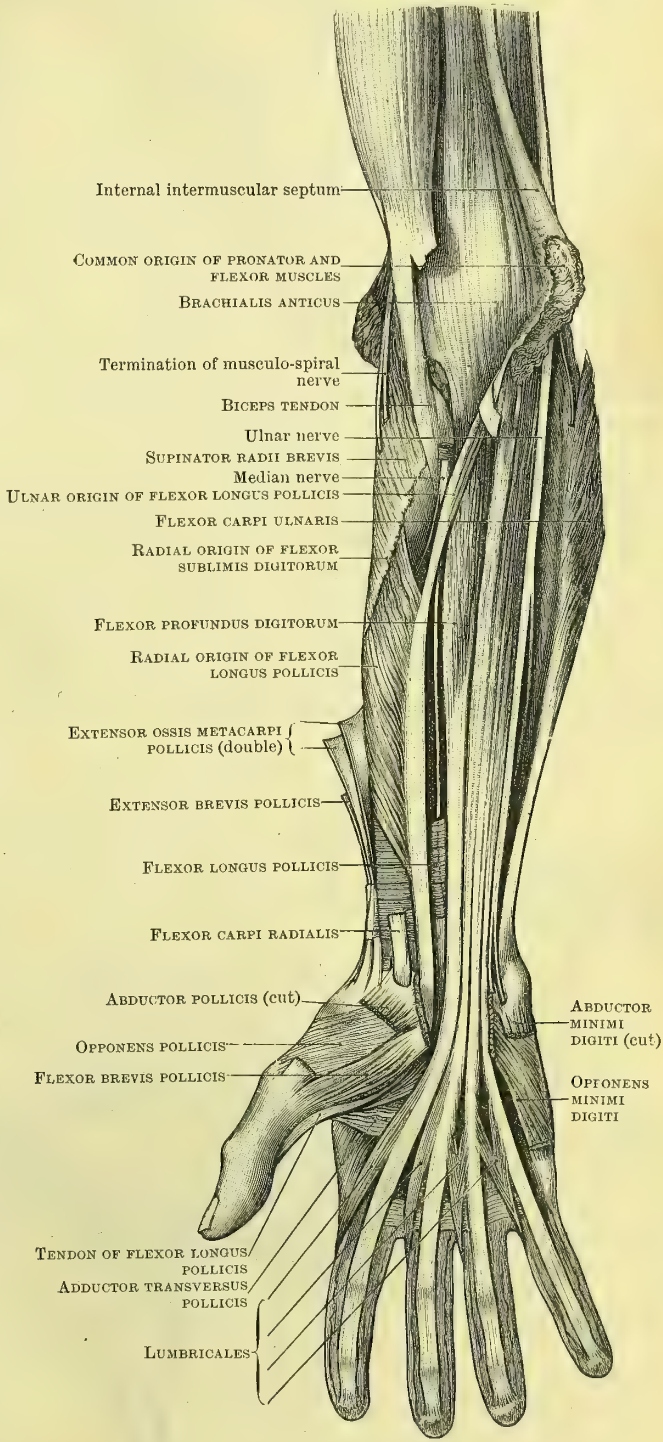


Fig. 243.—Deep Muscles on the Front of the Forearm and Hand.

are concealed by the tendons of the flexor sublimis digitorum. On the finger each tendon is placed at first beneath, and afterwards upon, the tendon of the flexor sublimis digitorum, in its passage through the digital sheath. The lumbrical muscles passing downwards on the radial side of the deep flexor tendons lie beneath the digital vessels and nerves on their way to their insertion.

The **flexor longus pollicis** arises from the anterior surface of the radius in its middle two-fourths, and from a corresponding portion of the interosseous membrane. Its radial origin is limited above by the oblique line and the origin of the flexor sublimis digitorum, and below by the insertion of the pronator quadratus muscle. The muscle ends above the wrist in a tendon, which passes into the hand beneath the anterior annular ligament, enveloped in a special synovial sheath. In the palm the tendon is directed downwards along the inner side of the thenar eminence, between the flexor brevis and adductor muscles of the thumb, to be **inserted** into the terminal phalanx of the thumb.

In the forearm the muscle is deeply placed beneath the flexor sublimis digitorum. The radial artery lies upon it, and the anterior interosseous artery and nerve intervene between it and the flexor profundus digitorum. It crosses over the insertion of the pronator quadratus near the wrist.

The **pronator quadratus** is a quadrilateral muscle, occupying the lower fourth of the forearm. It **arises** from the lower fourth of the anterior border and surface of the ulna, and is directed outwards to be **inserted** into the lower fourth of the anterior surface of the radius.

The muscle is deeply placed beneath the flexor tendons, the radial and ulnar arteries, and the ulnar and median nerves. It conceals the lower part of the interosseous membrane, the radius and ulna, and the anterior interosseous artery and nerve, which pass behind its upper border. The pronator quadratus is subject to considerable variations. It may even be absent; or it may have an origin from radius or ulna, or from both bones, and an insertion into the carpus.

SHORT MUSCLES OF THE HAND.

Muscles of the Thumb.

The **abductor pollicis** (m. abductor pollicis brevis) **arises** from the anterior annular ligament and the ridge of the trapezium. Strap-like in form, it is **inserted**

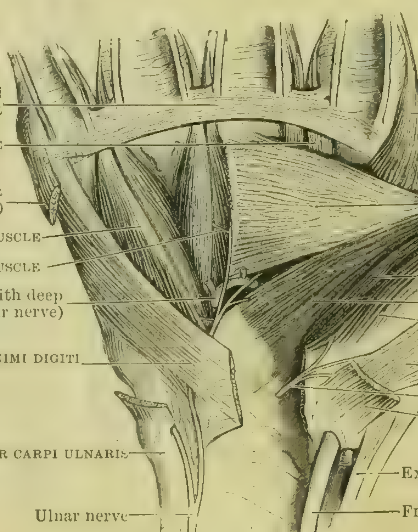


Fig. 244.—Short Muscles of the Hand.

into the outer side of the first phalanx of the thumb and the capsule of the metacarpo-phalangeal joint.

It is the most superficial muscle of the thenar eminence, and conceals partially the opponens, and the superficial portion of the flexor brevis pollicis.

The **opponens pollicis** arises beneath the preceding muscle from the annular ligament and the ridge on the trapezium. Extending downwards and outwards, it is **inserted** into the whole length of the first metacarpal bone on its anterior surface. The muscle is superficial along the outer border of the abductor pollicis.

The **flexor brevis pollicis** consists of two parts. *a. The superficial part of the muscle* arises from the anterior annular ligament, and is **inserted** into the outer side of the base of the first phalanx of the thumb, a sesamoid bone being present in the tendon of insertion. This part of the muscle, partly concealed by the abductor pollicis, is superficial in the interval between that muscle and the tendon of the flexor longus pollicis.

b. The deep part of the muscle (interrosseus primus volaris) **arises** from the ulnar side of the base of the first metacarpal bone, and is **inserted** into the inner side of the base of the first phalanx of the thumb along with the adductor obliquus pollicis. This little muscle is deeply situated in the first interosseous space, in the interval between the adductor obliquus pollicis and the first dorsal interosseous muscle. It may be regarded as homologous with the palmar interossei muscles, with which it is in series.

The **adductor obliquus pollicis** arises from the anterior surfaces of the trapezium, trapezoid, and os magnum, from the tendon of the flexor carpi radialis, and from the bases of the second and third metacarpal bones. It is **inserted** by a tendon, in which a sesamoid bone is developed, into the inner side of the base of the first phalanx of the thumb. At its outer border a slender slip separates from the rest of the muscle, and passing obliquely beneath the tendon of the flexor longus pollicis, is inserted into the outer side of the base of the first phalanx along with the superficial part of the flexor brevis pollicis.

The adductor obliquus pollicis lies on the ulnar side of the tendon of the flexor longus pollicis, internal to the thenar eminence. It is covered by the flexor tendons of the thumb and fingers, and conceals the radial artery and the deep part of the flexor brevis pollicis. At its inner border the radial artery (deep palmar arch) appears between it and the adductor transversus pollicis.

The **adductor transversus pollicis** arises from the front of the third metacarpal bone, in its lower two-thirds. Triangular in form, it is directed outwards, to be **inserted** into the inner side of the base of the first phalanx of the thumb along with the adductor obliquus. Lying beneath the flexor tendons, this muscle conceals the interossei muscles of the first two spaces and the radialis indicis and princeps pollicis arteries. Its upper border is separated from the adductor obliquus pollicis by the radial artery (deep palmar arch).

Muscles of the Little Finger.

The **abductor minimi digiti** (m. abductor digiti quinti) **arises** from the pisiform bone and the tendon of the flexor carpi ulnaris, and is **inserted** into the inner side of the base of the first phalanx of the little finger. It lies superficially upon the opponens and flexor brevis minimi digiti.

The **opponens minimi digiti** (m. opponens digiti quinti) **arises** from the anterior annular ligament and the hook of the unciform bone, and is **inserted** into the whole length of the fifth metacarpal bone along its inner margin.

It is concealed by the previous muscle, and may be pierced near its origin for the passage of the deep branches of the ulnar artery and nerve.

The **flexor brevis minimi digiti** (m. flexor digiti quinti brevis) **arises** from the anterior annular ligament and the hook of the unciform bone, and is **inserted** along with the abductor into the inner side of the first phalanx of the little finger.

This muscle is placed external to the opponens and abductor, and is separated from the latter by the deep branches of the ulnar artery and nerve. It may be reduced in size, absent altogether, or incorporated with either the opponens or abductor minimi digiti.

THE INTEROSSEOUS MUSCLES.

The interosseous muscles of the hand are arranged in two sets, palmar and dorsal.

The **palmar interossei** (m. interossei volares) are three in number, occupying the three inner interosseous spaces. Each **arises** by a single head; the *first* from the ulnar side of the shaft of the second metacarpal bone; the *second* and *third* from the radial sides of the shafts of the fourth and fifth metacarpal bones respectively. Each ends in a tendon which is directed downwards behind the deep transverse metacarpal ligament, to be **inserted** into the dorsal expansion of the extensor tendon, the capsule of the metacarpo-phalangeal articulation, and the side of the first phalanx of the fingers; the *first* is **inserted** into the ulnar side of the second finger; the *second* and *third* into the radial side of the fourth and fifth fingers.

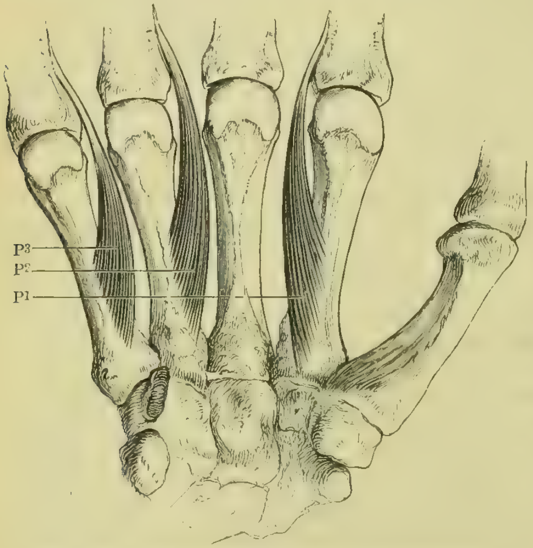


FIG. 245.—THE PALMAR INTEROSSEOUS MUSCLES.
P^1, first; P^2, second; and P^3, third palmar interosseous muscles.

The **dorsal interossei** are four in number. Each **arises** by two heads from the sides of the metacarpal bones bounding each interosseous space. Each forms a fleshy mass, and ends in a membranous tendon, which, passing downwards behind the transverse metacarpal ligament, is **inserted** exactly like the palmar muscles into the dorsal aspect of each of the four fingers. The insertion of the *first* dorsal inter-

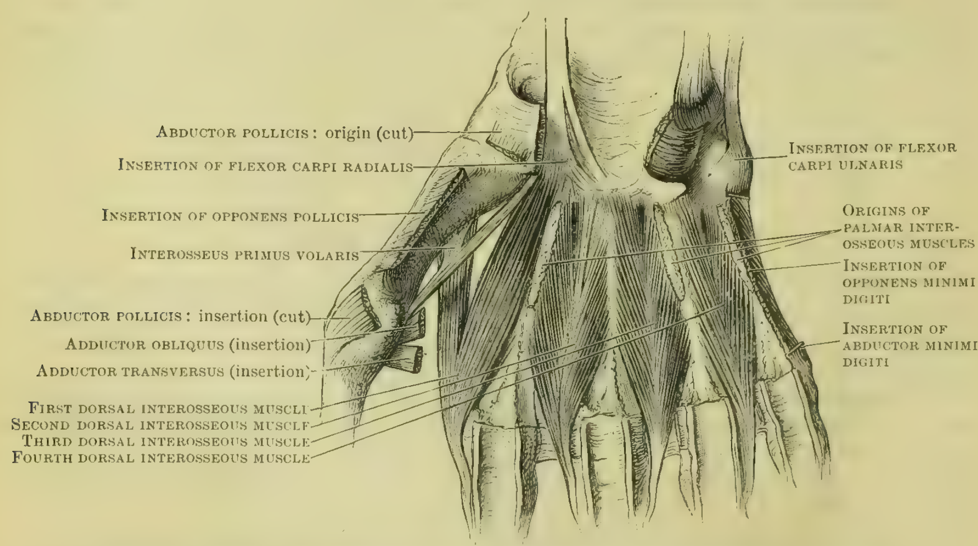


FIG. 246.—DORSAL INTEROSSEOUS MUSCLES OF THE HAND (seen from the Palmar Aspect).

osseous muscle is into the radial side of the index finger; the *second* muscle is attached to the radial side of the third finger; the *third* muscle to the ulnar side of the same finger; and the *fourth* muscle to the ulnar side of the fourth finger.

These muscles fill up the interosseous spaces; the dorsal interossei are visible on the back of the hand when the extensor tendons are removed; in the palm the

muscles are concealed by the flexor tendons and the muscles of the thumb and little finger, and are crossed by the deep palmar arch and the deep branch of the ulnar nerve. Between the two heads of the first dorsal muscle the radial artery enters the palm, and the perforating arteries pass between the heads of the other dorsal muscles.

The interossei muscles of the hand in some cases have a disposition similar to that of the corresponding muscles of the foot.

THE MUSCLES ON THE BACK OF THE FOREARM.

The group of muscles occupying the outer side of the elbow and the back of the forearm and hand include the supinator muscles of the forearm and the extensors of the wrist and digits. They are divisible into a **superficial** and a **deep layer.**

Superficial Muscles.

The **superficial layer** comprises seven muscles, viz. from without inwards, the brachio-radialis, the two radial extensors of the carpus, the extensor communis digitorum and extensor minimi digiti, the extensor carpi ulnaris, and the anconeus.

The **brachio-radialis arises** from the upper two-thirds of the external supra-condyloid ridge of the humerus, and from the external intermuscular septum. Occupying the outer side of the hollow of the elbow, the muscle descends along the outer border of the forearm, and ends about the middle in a narrow flat tendon which is **inserted** into the ridge on the front of the base of the styloid process of the radius.

The muscle is superficial in its whole length. Near its origin it is separated from the brachialis anticus by the musculo-spiral nerve. It forms the outer boundary of the hollow of the elbow, and conceals the radial extensors of the carpus, and, in the upper two-thirds of the forearm, the radial artery and nerve.

The **extensor carpi radialis longior** (m. ext. carp. rad. longus) **arises** from the lower third of the external supracondyloid ridge of the humerus, from the external intermuscular septum, and from the common tendon of origin of succeeding muscles from the external condyle. It ends in a tendon in the lower half of the forearm, which passes beneath the posterior annular ligament, to be **inserted** into the back of the base of the second metacarpal bone.

The upper part of the muscle is concealed by the brachio-radialis, and the lower part is crossed by the extensors of the thumb. It covers the supinator brevis and extensor carpi radialis brevior above, and the back of the radius and the carpus below.

The **extensor carpi radialis brevior** (m. ext. carp. rad. brevis) **arises** from the common tendon, from the external lateral ligament of the elbow, from the fascia over it, and from intermuscular septa on each side. It passes down the back of the forearm in close relation to the previous muscle, to be **inserted** by a tendon into the back of the base of the third metacarpal bone. A bursa is placed beneath the two radial extensor tendons close to their insertion.

Partially concealed by the extensor carpi radialis longior and the extensor muscles of the thumb, and having the extensor communis digitorum on its inner side, the muscle covers the supinator brevis and the lower part of the radius.

The **extensor communis digitorum arises** from the common tendon, from the fascia over it, and from intermuscular septa on each side. Extending down the back of the forearm, it ends above the wrist in four tendons, of which the outermost often has a separate fleshy belly. After passing beneath the posterior annular ligament in a compartment along with the extensor indicis, the tendons separate on the back of the hand, where the three innermost tendons are joined together by two obliquely-placed bands. One passes downwards and outwards, and connects together the third and second tendons; the other is a broader and shorter band, which passes also downwards and outwards, and joins the fourth to the third tendon.

The tendons are **inserted** in the following manner:—On the finger each tendon spreads out so as to form a membranous expansion over the knuckle and on the back of the first phalanx. The border of the tendon is indefinite over the metacarpo-phalangeal articulation, of which it forms the posterior ligament. On the back of the first phalanx the tendon receives laterally the insertions of the interossei and lumbrical muscles. At the lower end of the first phalanx the tendon splits into ill-defined median and lateral slips, proceeding over the back of the first inter-phalangeal articulation, of which they form the posterior ligament. The median slip is inserted into the back of the base of the second phalanx, while the two lateral pieces become united to form a membranous tendon on the back of the second phalanx, which, after passing over the second interphalangeal articulation, is inserted into the base of the terminal phalanx.

The extensor communis digitorum is superficial in its whole length, and lies between the radial extensors of the carpus externally and the extensor minimi digiti internally. It conceals the supinator brevis and other deep muscles of the forearm, as well as the posterior interosseous vessels and nerves. The extensors of the thumb become superficial along its outer border in the lower third of the forearm.

The **extensor minimi digiti** (m. extensor digiti quinti proprius) has an **origin** similar to and closely connected with that of the preceding muscle, from the common tendon, the fascia over it, and lateral intermuscular septa. Passing down the back of the forearm as a narrow fleshy slip, between the extensor communis digitorum and the extensor carpi ulnaris, it ends in a tendon which occupies a groove between the radius and ulna in a special compartment of the posterior annular ligament; on the back of the hand the tendon, usually split in two parts, lies internal to the tendons of the extensor communis digitorum, and is finally **inserted** into the expansion of the extensor tendon on the dorsum of the first phalanx of the little finger.

The **extensor carpi ulnaris** has a double **origin**: (1) from the common tendon from the external condyle, from the deep fascia over it, and from the intermuscular septa; and (2) through the medium of the deep fascia, from the posterior border of the ulna in its middle two-fourths. The muscle ends in a tendon in the lower third of the forearm, which occupies a groove on the back of the ulna in a special compartment of the posterior annular ligament, and is **inserted** into the back of the base of the fifth metacarpal bone.

The muscle is superficially placed between the extensor minimi digiti and the anconeus, external to the posterior border of the ulna. It conceals the supinator brevis and the posterior interosseous vessels and nerve above, and in the lower two-thirds of the forearm covers the posterior surface of the ulna.

The **anconeus** is a small triangular muscle **arising** by a separate tendon from the back of the external condyle of the humerus. Spreading out over the ulna, it is **inserted** into a triangular surface on the outer side of the olecranon process and back of the ulna, as low down as the oblique line.

It is covered by the thickened fascia of the forearm giving insertion to the triceps muscle. It conceals the back of the elbow joint and part of the origin of the supinator brevis muscle.

The **epitrochleo-anconeus** is an occasional small muscle **arising** from the back of the internal condyle of the humerus, and **inserted** into the inner side of the olecranon process. It covers the ulnar nerve in its passage to the forearm.

Deep Muscles.

The **deep muscles** of the back of the forearm comprise five muscles, of which one, the supinator radii brevis, extends between the ulna and radius; the others are extensors of the thumb and forefinger: the extensor ossis metacarpi pollicis, extensor brevis and extensor longus pollicis, and extensor indicis.

The **supinator radii brevis** (m. supinator) muscle has a complex **origin**: (1) from the external condyle of the humerus; (2) from the external lateral and orbicular ligaments of the elbow joint; (3) from the triangular surface on the ulna below the lesser sigmoid cavity; and (4) from the fascia over it. From this origin

the muscle spreads outwards and downwards, enveloping the upper part of the radius, and is **inserted** into the anterior and outer surfaces of the bone, as far forwards as the bicipital tubercle, as far upwards as the neck, and as far downwards as the oblique line and the insertion of the pronator radii teres.

The supinator brevis is deeply placed, and is uncovered only anteriorly in the hollow of the elbow. It is covered by all the superficial muscles on the back of the forearm. It conceals the back of the elbow joint and the upper part of the radius. At its lower border is the extensor ossis metacarpi pollicis, separated from it by the posterior interosseous artery. The muscle is divisible into *superficial* and *deep parts* with humeral and ulnar regions, between which the posterior interosseous nerve passes to reach the back of the forearm.

The **extensor ossis metacarpi pollicis** (m. abductor pollicis longus) **arises** below the supinator brevis from the posterior or extensor surfaces of the radius and ulna, and from the intervening portion of the interosseous membrane. Becoming superficial in the lower part of the forearm along with the extensor brevis pollicis, it passes beneath the posterior annular ligament, to be **inserted** into the outer side of the base of the first metacarpal bone.

At its origin the muscle is deeply placed beneath the superficial extensor muscles and the posterior interosseous vessels and nerve. Above is the supinator brevis; below and internally, the long and short extensors of the thumb. In the lower third of the forearm it becomes superficial along with the extensor brevis pollicis, between the extensor communis digitorum and the radial extensors of the carpus. It covers the last-named

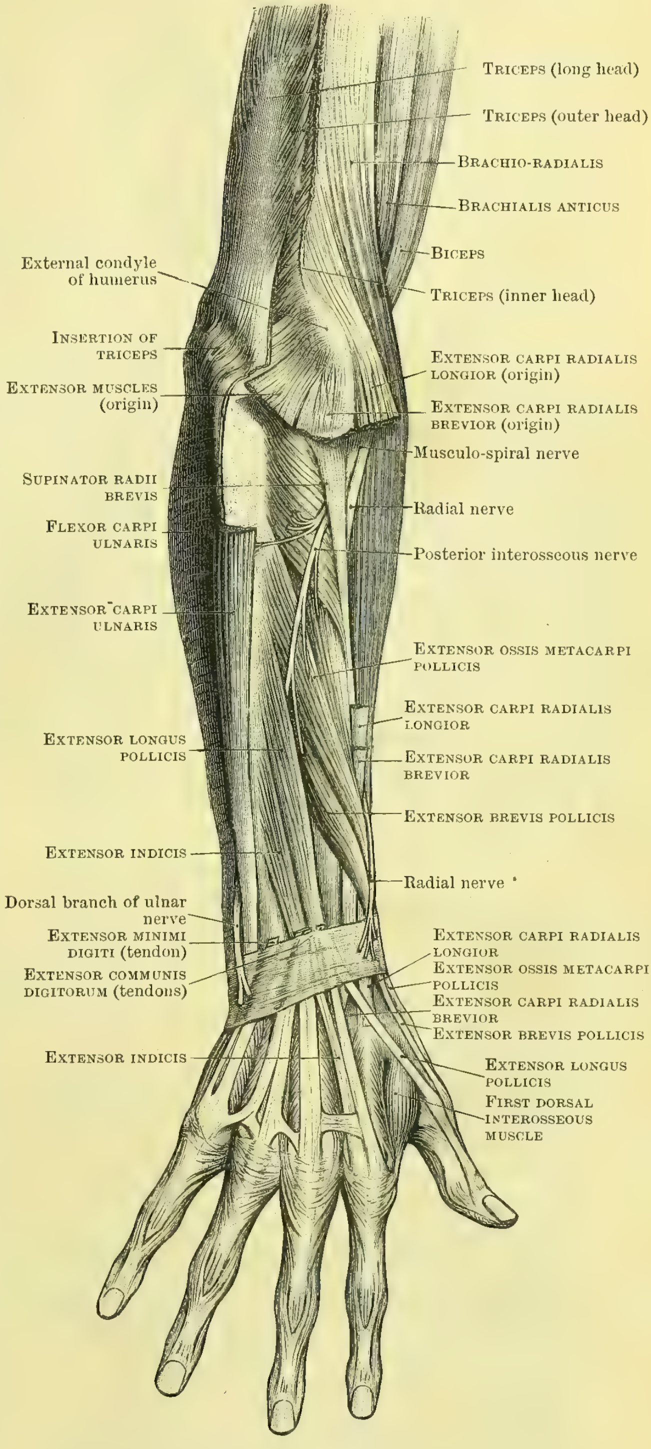


Fig. 247.—The Muscles of the Back of the Forearm (the superficial muscles being reflected).

muscles in its further course in the forearm, and at the wrist it crosses the radial artery.

The **extensor brevis pollicis**, an essentially human muscle, is a specialised portion of the previous muscle. It **arises** from the back of the radius and the interosseous membrane below the extensor ossis metacarpi pollicis. It is closely adherent to that muscle, and accompanies it beneath the posterior annular ligament and over the radial artery to the thumb. Its tendon is then continued along the back of the first metacarpal bone, and the metacarpo-phalangeal articulation, to be **inserted** into the base of the first phalanx of the thumb. Before reaching its insertion the tendon helps to form the capsule of the metacarpo-phalangeal joint. In the forearm the muscle is deeply placed beneath the superficial extensors, and is separated from the extensor longus pollicis by the posterior interosseous nerve.

The **extensor longus pollicis arises** from the posterior or extensor surface of the ulna, and from the interosseous membrane, below the extensor ossis metacarpi pollicis. Its tendon grooves the back of the radius, and occupies a special compartment beneath the posterior annular ligament. Extending obliquely across the back of the hand, it is **inserted** into the base of the second phalanx of the thumb.

The muscle is deeply placed beneath the superficial extensors of the forearm, and lies between the extensor brevis pollicis and the extensor indicis. It separates the posterior interosseous artery from the nerve, the latter passing beneath it. On the back of the hand the tendon crosses the radial artery, and helps to form the capsule of the first metacarpo-phalangeal articulation.

The **extensor indicis** (m. extensor indicis proprius) **arises** below the extensor longus pollicis from the back of the ulna, and sometimes also from the interosseous membrane. Its tendon passes through a compartment of the posterior annular ligament along with the tendons of the extensor communis digitorum, and is **inserted** into the forefinger, joining the membranous expansion of the tendon of the extensor communis digitorum on the dorsum of the first phalanx.

Lying deeply in the forearm, the muscle is placed internal to the extensor longus pollicis, and covers the posterior interosseous nerve. On the back of the hand its tendon lies on the inner side of the tendon of the common extensor destined for the forefinger.

Nerve Supply.

Four nerves are engaged in supplying the muscles of the forearm and hand—the median and ulnar on the front, the musculo-spiral and posterior interosseous nerves on the back of the limb.

Muscles.	Nerves.	Origin.
A. Pronators and Flexors.		
Pronator radii teres Flexor carpi radialis Palmaris longus Flexor sublimis digitorum	Median	C. 6.
Flexor carpi ulnaris	Ulnar	C. 8. T. 1.
Flexor profundus digitorum	Ulnar and anterior interosseous (median)	C. 8. T. 1. C. 7. 8. T. 1.
Flexor longus pollicus Pronator quadratus	Anterior interosseous	C. 7. 8. T. 1.
B. Muscles of the Hand.		
Abductor pollicis Opponens pollicis Flexor brevis pollicis (superficial)	Median	C. 6. 7.
Flexor brevis pollicis (deep) Adductor obliquus pollicis Adductor transversus pollicis	Ulnar	C. 8. (T. 1).
Lumbricales 1st and 2nd	Median	C. 6. 7.
Lumbricales 3rd and 4th Interossei Flexor brevis minimi digiti Opponens minimi digiti Abductor minimi digiti	Ulnar	C. 8. (T. 1).

Muscles.	Nerves.	Origin.
C. **Supinators and Extensors.**		
Brachio-radialis	Musculo-spiral	C. 5. 6.
Extensor carpi radialis longior	Musculo-spiral	C. 6. 7.
Extensor carpi radialis brevior		C. 6. 7.
Extensor communis digitorum Extensor minimi digiti Extensor carpi ulnaris	Posterior interosseous (musculo-spiral)	C. 6. 7. 8.
Anconeus	Musculo-spiral	C. 7. 8.
Supinator radii brevis		C. 6.
Extensor ossis metacarpi pollicis Extensor brevis pollicis Extensor longus pollicis Extensor indicis	Posterior interosseous	C. 6. 7. 8.

ACTION OF THE MUSCLES OF THE FOREARM AND HAND.

The muscles of the forearm and hand are concerned in the movements of the elbow, wrist, and joints of the fingers.

In the majority of cases the muscles act upon more than one joint.

1. Action on the Elbow Joint.—It has been shown already (p. 330) that flexion and extension of the elbow are assisted by certain of these muscles. The **flexor muscles** are the pronator radii teres, and the flexor muscles of the wrist and fingers, along with the brachio-radialis and extensors of the wrist and fingers (during pronation). The **extensors** are the supinator brevis and anconeus, and the extensor muscles of the wrist and fingers (during supination).

2. Pronation and supination of the hand are performed by special muscles, aided by muscles which act also upon other joints. The brachio-radialis assists in flexion and pronation on the one hand, and in extension and supination on the other hand.

Pronation.	Supination.
Pronator radii teres	Supinator radii brevis
Pronator quadratus	Biceps
Brachio-radialis	Brachio-radialis
Flexor carpi radialis	Extensors of thumb and fingers
Weight of the limb	Weight of the limb

3. Action on the Wrist Joint.—The movements at the wrist joint are flexion and extension, abduction and adduction. The following muscles produce these movements :—

a. **Flexion** and	**Extension.**	*b.* **Adduction** and	**Abduction.**
Flexor carpi radialis Palmaris longus Flexor carpi ulnaris Long flexors of thumb and fingers	Extensors of the wrist Extensors of thumb and fingers	Flexor carpi ulnaris Extensor carpi ulnaris	Flexor carpi radialis Extensors of wrist Extensors of thumb

4. Movements of the Fingers.—Two separate series of movements occur in relation to the articulations of the fingers: flexion and extension (at the metacarpo-phalangeal and interphalangeal joints), and abduction and adduction (only at the metacarpo-phalangeal joints). The movements and the muscles concerned are given in the following table :—

a. **Flexion** and	**Extension.**
Flexor sublimis digitorum Flexor profundus digitorum Lumbricales, Interossei (*acting on the metacarpo-phalangeal articulations*) Flexor brevis minimi digiti	Extensor communis digitorum Extensor indicis Extensor minimi digiti Lumbricales, Interossei (*acting on the inter-phalangeal articulations*)

b. **Abduction**	and **Adduction.**
Lumbricales, Flexor brevis and Opponens minimi digiti (from the inner side of the hand)	
Dorsal interossei (from the middle line of the middle finger)	Palmar interossei (to the middle line of the middle finger)

Flexion is more powerful and complete than extension of the fingers. The flexor profundus alone acts on the terminal phalanges; the flexor sublimis and flexor profundus together flex the proximal interphalangeal joint; and flexion of the metacarpo-phalangeal articulation is effected by these muscles, assisted by the interossei, lumbricales, and flexor brevis minimi digiti. Extension of the phalanges is effected by the united action of the extensors of the digits, the interossei and lumbricales; extension of the fingers at the metacarpo-phalangeal joints is produced solely by the long extensor muscles. *Separate extension of the index finger* only is possible; the three inner fingers can only be flexed and extended together, on account of the connecting bands joining the extensor tendons together on the back of the hand.

5. Movements of the Thumb.—The movements of which the thumb is capable are flexion and extension (occurring at the carpo-metacarpal, metacarpo-phalangeal, and interphalangeal joints); abduction and adduction, together with circumduction (occurring at the carpo-metacarpal joint).

The muscles and their respective actions are given in the following table :—

a. **Flexion**	and **Extension.**
Opponens pollicis (carpo-metacarpal joint)	Extensor ossis metacarpi pollicis (carpo-metacarpal joint)
Flexor brevis, Adductors, Abductor (carpo-metacarpal and metacarpo-phalangeal joint)	Extensor brevis pollicis (carpo-metacarpal and metacarpo-phalangeal joint)
Flexor longus pollicis (all joints)	Extensor longus pollicis (all joints)
b. **Adduction**	and **Abduction.**
Adductors of the thumb Flexor brevis, Opponens pollicis First dorsal interosseous	Abductor pollicis Extensors of the thumb
c. **Circumduction**—a combination of the above muscles.	

The characteristic features of the movements of the upper limb are their range and refinement. The hand, in addition to its intrinsic powers, can be moved through a wide range and in several planes by the muscles acting on the wrist and radio-ulnar joints; this range is increased by the fore and aft movements at the elbow-joint, and the extensive movements of which the shoulder and clavicular joints are capable. The result is that the hand can be brought into a position to cover and guard any portion of the body. The precision and refinement of movement is made possible by the co-ordinate movements of the various muscles acting upon the several joints, so that actions can be performed (as eating) in which all the articulations of the limb are brought into play; while others (such as writing) are possible by movements at the joints of the wrist and fingers along with fixation of the elbow-joint.

THE LOWER LIMB.

FASCIÆ AND MUSCLES OF THE THIGH AND BUTTOCK.

FASCIÆ.

The **superficial fascia** of the thigh and buttock is continuous above with the fascia of the abdomen and back, internally with that of the perineum, and below with that of the leg. It presents noticeable features in the buttock and groin.

In the buttock the superficial fascia is of considerable thickness, and usually loaded with fat, whereby it assists in forming the contour of the buttock and the fold of the nates.

In the groin it is divisible into *two layers:* a **superficial fatty layer,** continuous with a similar layer on the front of the abdominal wall above, and over the perineum internally, and a **deeper membranous layer,** which is attached above to the inner half of Poupart's ligament, and to the deep fascia of the thigh just below the outer half of that ligament. Internally it is attached to the pubic arch, and below the level of Scarpa's triangle it blends inseparably with the superficial fatty layer. The separation of these two layers of the superficial fascia is occasioned by the presence between them of the femoral and inguinal lymphatic glands, the internal saphenous vein and its tributaries, and some small arteries. The attachment of the deeper layer of the fascia to the pubic arch and Poupart's ligament cuts off the superficial tissues of the thigh from the perineum and the anterior abdominal wall, and prevents the passage down the thigh of fluid collected in the perineum or beneath the fascia of the anterior abdominal wall.

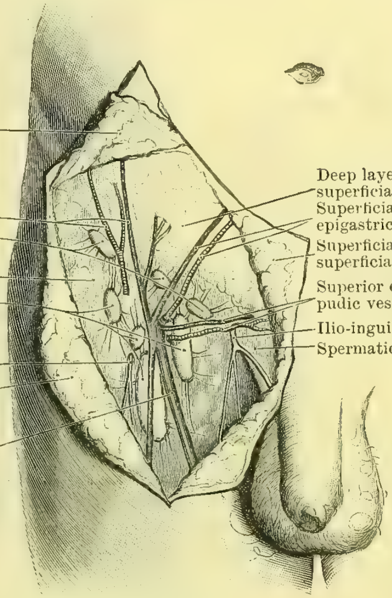


FIG. 248.—THE GROIN. STRUCTURES BETWEEN THE LAYERS OF THE SUPERFICIAL FASCIA.

The **deep fascia** or **fascia lata** forms a tubular investment for the muscles and vessels of the thigh and buttock. It is firmly attached above to the iliac crest, the great sacro-sciatic ligament, the ischium, the pubic arch, the pubic symphysis and crest, and Poupart's ligament. Below, in relation to the knee, it is continuous with the deep fascia of the leg, gains attachment to the patella, the tuberosities of the tibia and the head of the fibula, and forms the lateral ligaments of the patella.

On the front of the thigh the deep fascia is thick and strong. It is pierced by numerous openings for vessels and nerves, the most important of which is the **saphenous opening** for the internal saphenous vein. A femoral hernia passes through this opening to reach the anterior abdominal wall. It is an oval opening of variable size situated just below the inner half of Poupart's ligament, and immediately in front of the femoral vessels. It is covered by the superficial fascia, and by a special layer of fascia, the **cribriform fascia,** a thin perforated lamina, attached to the margins of the opening. The outer edge of the opening is formed by the margin of the *iliac portion* of the fascia lata which is attached above to the iliac crest and Poupart's ligament; the inner edge is formed by the margin of the *pubic portion* of the fascia lata, which is continued upwards behind the femoral sheath, over the adductor longus and pectineus muscles to the ilio pectineal line and the capsule of the hip-joint. These two layers of the fascia lata are continuous at the lower concave margin of the saphenous opening, forming its **inferior cornu.** As they pass upwards towards the pelvis they occupy different planes, the iliac portion being in front of the femoral sheath, the pubic portion of the fascia behind it. The **superior cornu** of the saphenous opening, placed

in front of the sheath, is derived solely from the iliac portion of the fascia lata. It forms a strong triangular band of fascia attached above to the inner half of Poupart's ligament, and is known as the **falciform ligament.** It has an important share in directing the course of a femoral hernia upwards on to the abdominal wall.

Internally in relation to the adductor muscles of the thigh the fascia lata becomes much thinner. *At the knee* it is associated with the tendons of the vasti muscles, and forms the **lateral ligaments of the patella**, attached to the borders of the patella and to the tuberosities of the tibia. *Externally* it gives rise to the

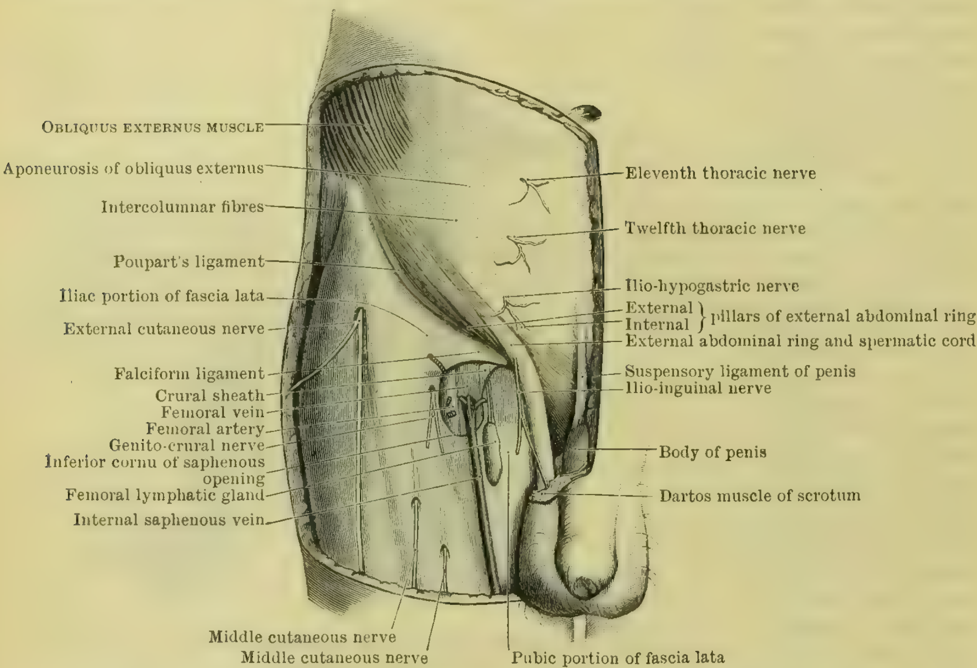


Fig. 249.—The Groin—the Structures seen on removal of the Superficial Fascia.

ilio-tibial band—a broad thick layer of fascia which is attached above to the iliac crest, and receives the insertions of two muscles in the upper part of the thigh—the tensor fasciæ femoris, and part of the gluteus maximus; it is attached below to the capsule of the knee-joint and the outer tuberosity of the tibia. The fascia beneath the tensor fasciæ femoris muscle, continued upwards from the ilio-tibial band, sends a strong band inwards which joins the origin of the rectus femoris and the capsule of the hip-joint.

On either side of the thigh above the knee an intermuscular septum is formed; the **external intermuscular septum** extends inwards from the ilio-tibial band to the external supra-condyloid ridge of the femur, and gives attachment to the vastus externus and crureus in front, and the short head of the biceps behind. The **internal intermuscular septum** is more complex. It is represented by a layer of fascia which forms separate envelopes for the gracilis and sartorius muscles, and in the upper and middle thirds of the thigh encloses the adductor muscles. In the lower third of the thigh it is for the most part replaced by the tendon of the adductor magnus; in the middle third of the thigh the fascia is specially thickened by transverse fibres connecting together the adductor muscles and the vastus internus. This sheet of fascia forms a special aponeurosis beneath the sartorius, which roofs over the femoral artery in Hunter's canal.

The **fascia lata of the buttock** is thick anteriorly in relation to the gluteus medius, thinner posteriorly over the gluteus maximus, at the upper border of which it splits to enclose and assist in forming the insertion of the muscle.

On the back of the thigh and over the **popliteal space** the fascia is strengthened by transverse fibres derived from the hamstring muscles. The **popliteal fascia**

forming the roof of the popliteal space is specially thick, and is usually pierced by the external saphenous vein.

A **femoral hernia** appears in the thigh through the saphenous opening, thereafter passing upwards over Poupart's ligament to the anterior abdominal wall.

Femoral Sheath.—This is a conical membranous investment for the femoral

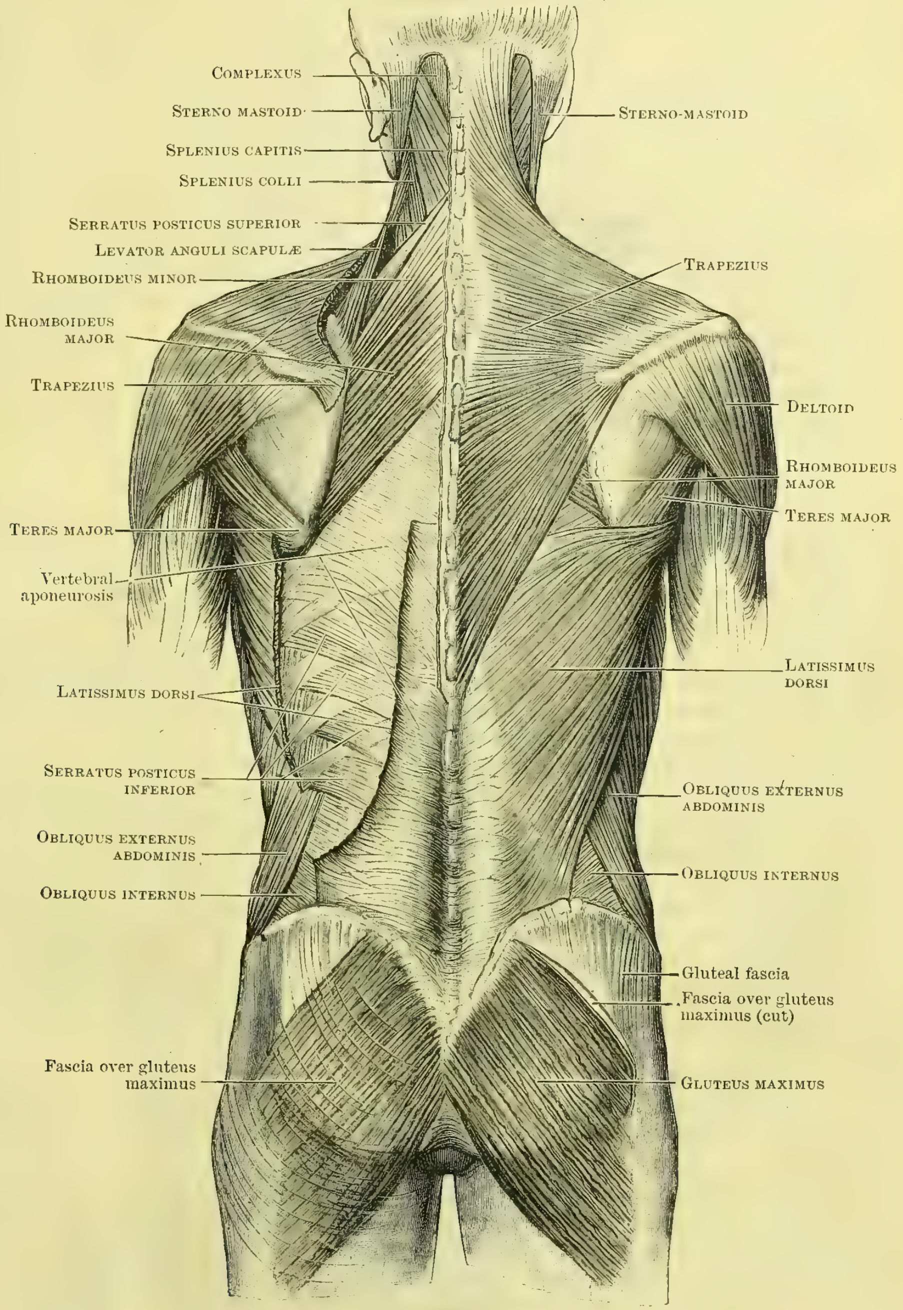


Fig. 250.—Superficial Muscles of the Back.

vessels, prolonged into Scarpa's triangle beneath Poupart's ligament, and continuous above with the internal fascial lining of the abdominal wall, formed by the fascia transversalis in front and the fascia iliaca behind. The sheath is divided into three compartments—an external space for the artery, an intermediate space for the vein, and an internal channel containing lymphatics, and

named the **crural canal**. The wall of this is known as the **crural sheath**. This canal is the passage through which a femoral hernia enters the thigh. Its upper limit is the **crural ring**, placed behind Poupart's ligament in front of the origin of the pectineus muscle from the pubis; external to Gimbernat's ligament, and internal to the femoral vein. In front of it the fascia transversalis forming the sheath is thickened to form the **deep crural arch**. The part of Poupart's ligament in front of the ring is called the **superficial crural arch**. The deep epigastric artery separates the crural ring from the internal abdominal ring. The crural canal ordinarily contains fat which is continuous above with the extra-peritoneal tissue. The crural ring is filled by a plug of fat or a lymphatic gland, constituting the **crural septum**.

The crural canal ends behind the saphenous opening, covered by the cribriform fascia; the falciform ligament crosses over it and conceals its upper portion. The course of a femoral hernia is determined by this band of fascia lata. The hernia descends through the crural ring, pushing the crural septum before it; it traverses the crural canal, and is directed forwards through the saphenous opening. The anterior part of the hernia, being pressed upon and retarded by the crural arches and by the falciform ligament, the posterior part pushes onwards, hooks round the falciform ligament, and is directed upwards over Poupart's ligament. The coverings of a femoral hernia, in addition to peritoneum and extra-peritoneal tissue (crural septum), are crural sheath, cribriform fascia, superficial fascia, and skin.

THE MUSCLES ON THE FRONT OF THE THIGH.

The muscles on the front of the thigh include the sartorius, quadriceps extensor, ilio-psoas, and pectineus muscles.

The **sartorius**, a long strap-like muscle stretching obliquely across the thigh, **arises** from the anterior superior spine of the ilium and half of the notch below it. It passes down the thigh to the inner side of the knee, where it is **inserted** by aponeurotic fibres into the inner surface of the shaft of the tibia just below the inner tuberosity, and by its borders into fascial expansions which join the capsule of the knee-joint and the fascia lata of the leg.

The sartorius is superficial in its whole extent. It is so twisted on itself that in the upper third of its length its superficial surface looks forwards, in the lower third inwards at the side of the knee. It passes diagonally down the thigh, separating the quadriceps extensor externally from the adductor muscles internally. Its upper third forms the outer boundary of Scarpa's triangle; its middle third forms the roof of Hunter's canal; and its lower third, in contact with the inner side of the knee, is separated from the tendon of the gracilis muscle by the long saphenous nerve and a branch of the anastomotic artery. A bursa lies beneath the tendon at its insertion. The sartorius conceals in its upper third the external circumflex artery and branches of the anterior canal nerve, and it covers the femoral vessels in Hunter's canal.

The **quadriceps extensor** (m. quadriceps femoris) lies between the sartorius on the one hand and the tensor fasciæ femoris and ilio-tibial band on the other; it is composed of four muscles—the rectus femoris, vastus externus, crureus, and vastus internus.

The **rectus femoris** has a double tendinous **origin**. (1) The *straight head* arises from the anterior inferior spine of the ilium; (2) the *reflected head* springs from a rough groove on the dorsum ilii just above the highest part of the acetabulum. A bursa lies beneath this head of origin. The two heads, bound together and connected to the capsule of the hip-joint by a band of fascia derived from the under surface of the tensor fasciæ femoris (ilio-tibial band), give rise to a single tendon which extends for some distance on the front of the muscle, and from which the muscular fibres arise. The muscular fibres springing from this tendon, and also from a median septal tendon, present a bipennate arrangement, and end below in a broad tendon which passes upwards for some distance along the posterior surface of the muscle. This tendon gradually narrows towards the knee, and spreading out again, is **inserted** into the upper border of the patella. It receives

laterally parts of the insertions of the vasti muscles, and on its deep surface is joined by the tendinous insertion of the crureus.

The rectus femoris is superficial except at its origin, which is covered by the

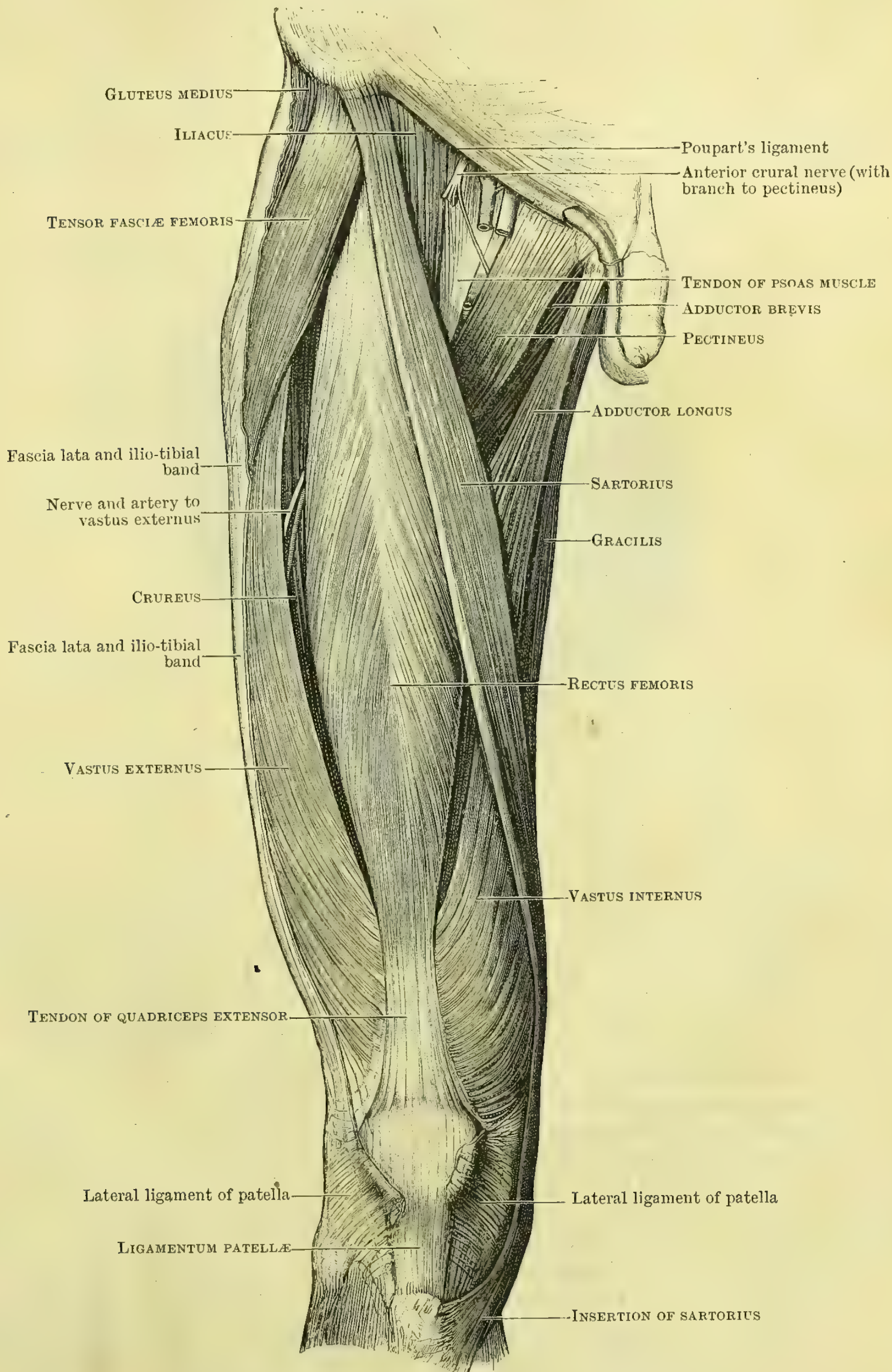


FIG. 251.—THE MUSCLES ON THE FRONT OF THE THIGH.

glutei, tensor fasciæ femoris, and sartorius muscles. On its inner side lie the iliacus, sartorius, and vastus internus; on its outer side are the tensor fasciæ femoris and vastus externus. It conceals the crureus muscle and branches of the external circumflex artery and anterior crural nerve. A bursa, which communicates with

the synovial membrane of the knee-joint, lies beneath its tendon in front of the lower end of the shaft of the femur.

The **vastus externus** (m. vastus lateralis) has an **origin**, partly fleshy, partly membranous, (1) from the shaft of the femur, from the anterior tubercle, along the lower border of the great trochanter, the gluteal ridge, and the upper half of the linea aspera; and (2) from the fascia lata and external intermuscular septum.

It forms a thick broad muscle directed downwards and forwards, and is **inserted** into (1) the outer border of the tendon of the rectus femoris, (2) the upper and outer border of the patella, and (3) the capsule of the knee-joint, and the

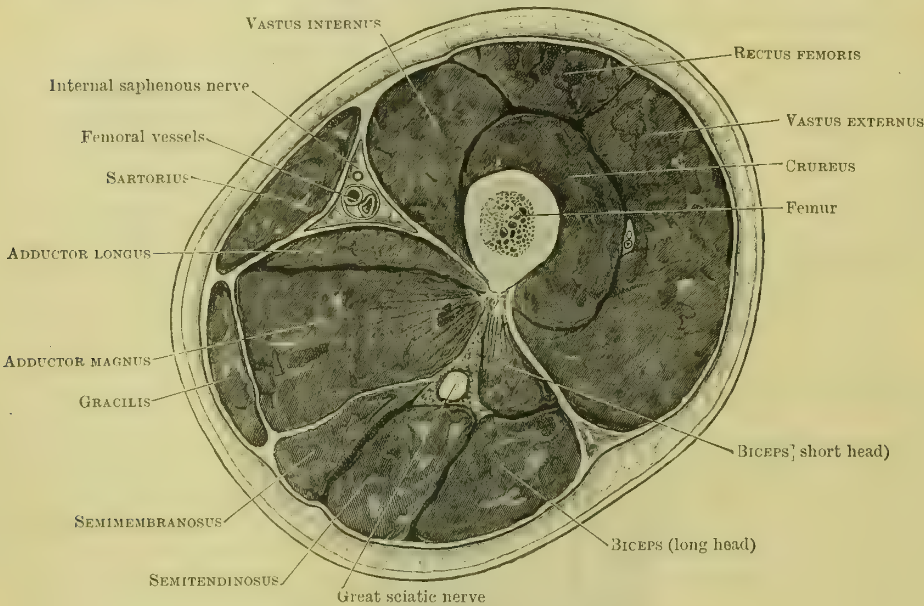


FIG. 252.—TRANSVERSE SECTION OF THE THIGH (HUNTER'S CANAL).

external lateral ligament of the patella. The vastus externus is covered superficially by the fascia lata and the ilio-tibial band. A bursa intervenes between it and the membranous insertion of the gluteus maximus: at its inner border is the rectus femoris; and along its outer border, but on a deeper level, is the crureus, which is also to a large extent concealed by the muscle. Between the vastus externus and crureus is the descending branch of the external circumflex artery.

The **vastus internus** (m. vastus medialis) is larger than the vastus externus and has a more extensive **origin**, from (1) the shaft of the femur, from the anterior tubercle, spiral line, linea aspera, and the upper two-thirds of the line leading from the linea aspera to the internal condyle of the femur; (2) the membranous expansion of the fascia lata which lies beneath the sartorius and forms the roof of Hunter's canal; and (3) the internal intermuscular septum and tendon of the adductor magnus.

From its origin the muscle is directed downwards and outwards towards the knee; it is **inserted** into (1) the inner border of the rectus tendon, (2) the upper and inner border of the patella, and (3) the capsule of the knee-joint and the internal lateral ligament of the patella. The vastus internus is superficial except at its origin, which is concealed by the sartorius and femoral vessels. Along its outer side are the rectus and crureus; the muscle conceals the inner side of the shaft of the femur and the crureus, with which it is closely incorporated in its lower two-thirds.

The **crureus muscle** (m. vastus intermedius) **arises** (1) from the upper two-thirds of the shaft of the femur on the anterior and external surfaces, (2) from the lower

half of the linea aspera and upper part of the line leading therefrom to the external condyle, as well as (3) from a corresponding portion of the external intermuscular septum.

For the most part deeply placed, the muscle is directed downwards to an **insertion** into the deep surface of the tendons of the rectus and vasti muscles by means of fibres which join a membranous expansion on its surface.

The crureus is concealed by the rectus and vasti muscles, and by the ilio-tibial band externally, in the lower half of the thigh. It is closely adherent to the vastus externus muscles in the middle third of the thigh; it is inseparable from the vastus internus below the upper third. Beneath the crureus is the femur; and in the lower third of the thigh it conceals the subcrureus muscle, a bursa, and the upward prolongation of the synovial membrane of the knee-joint.

The **subcrureus** consists of a number of separate bundles of muscular fibres **arising** beneath the crureus from the lower fourth of the front of the femur, and **inserted** into the synovial membrane of the knee-joint beneath the tendon of the rectus femoris.

The four elements composing the quadriceps extensor muscle have been traced in their convergence to the patella and the lateral ligaments of the patella. Their ultimate **insertion** is into the tibia, by means of the **ligamentum patellæ**, and the **lateral ligaments of the patella.** The patella, indeed, is in one sense a sesamoid bone formed in the tendon of the muscle, the ligamentum patellæ being the real tendon of insertion, and the lateral ligaments fascial expansions from its borders. The insertion of the muscle forms the front of the capsule of the knee-joint.

The **ilio-psoas muscle** is a compound muscle, consisting of one or sometimes two elements (**psoas, magnus and parvus**) connecting the femur and pelvic girdle to the axial skeleton; and another element, the **iliacus**, extending between the pelvis and the thigh. The muscles chiefly occupy the posterior wall of the abdomen and false pelvis, their insertions only appearing in the thigh below Poupart's ligament.

The **psoas magnus** (m. psoas major) is a large pyriform muscle, which has an extensive **origin** from the vertebral column in the lumbar region. It arises (1) from the intervertebral discs above each lumbar vertebra, and from the adjacent margins of the vertebræ—from the lower border of the 12th thoracic to the upper border of the 5th lumbar vertebra; (2) it arises also from four aponeurotic arches which pass over the sides of the bodies of the first four lumbar vertebræ; and (3) it has an additional origin posteriorly from the transverse processes of all the lumbar vertebræ. The fibres form a fusiform muscle directed downwards over the pelvic brim and beneath Poupart's ligament, ending in a tendon which is **inserted** into the apex of the lesser trochanter of the femur.

The psoas muscle occupies the posterior abdominal wall, the false pelvis and the thigh. In the abdomen it lies in the groove alongside the bodies of the lumbar vertebræ, in front of the transverse processes, and enveloped by a fascia derived from the lumbar aponeurosis. The abdominal viscera in contact with it are: the kidney and colon on both sides, with the duodenum on the right, and the pancreas on the left side. The ureter is in front of it, along with the spermatic or ovarian, the renal and colic vessels. The inferior vena cava is in front of the right muscle; the inferior mesenteric vein is in front of that of the left side. The lumbar plexus is imbedded in its substance, and the nerves of distribution emerge from its borders and surface. In the false pelvis the psoas covers the pelvic brim, and is covered by the ureter, the iliac vessels, the ileum on the right side, and the iliac colon on the left side. The vas deferens and spermatic vessels cross over it just above Poupart's ligament. In Scarpa's triangle the tendon is behind the femoral vessels, between the iliacus and pectineus, and in front of the obturator externus muscle and the hip-joint. A bursa, which may be continuous with the synovial cavity of the hip-joint, separates the tendon from the pubis and the capsule of the hip-joint.

The **psoas parvus** (m. psoas minor) is often absent (40 per cent). It **arises** from the intervertebral disc between the last thoracic and first lumbar vertebræ, and

from the contiguous margins of these vertebræ. It forms a slender fleshy belly, its margins blending with the fascia covering the psoas magnus, and is **inserted** by a narrow tendon into the middle of the ilio-pectineal line and the ilio-pectineal eminence.

The **iliacus muscle arises** mainly from a horseshoe-shaped origin around the

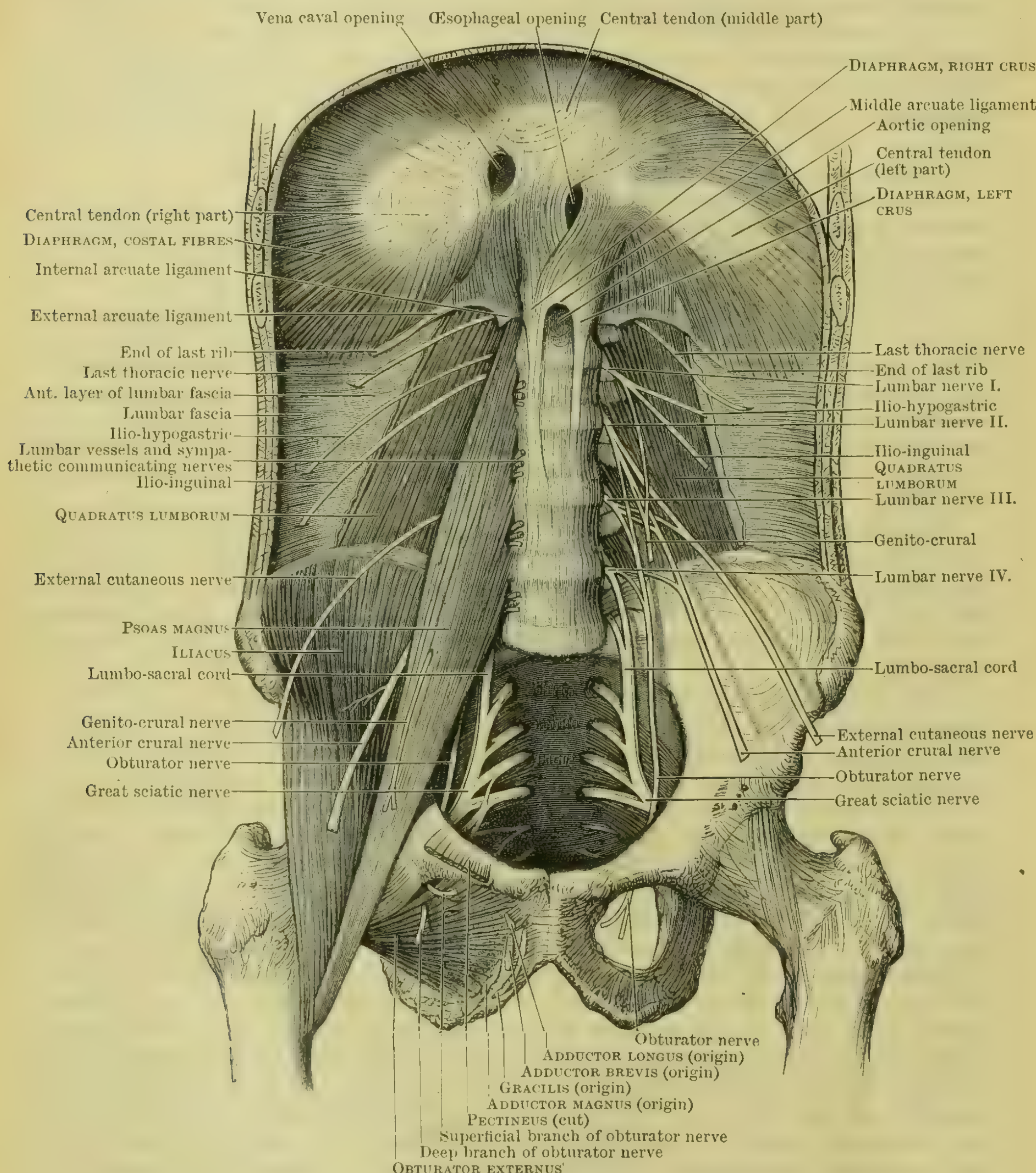


FIG. 253.—VIEW OF THE POSTERIOR ABDOMINAL WALL, TO SHOW THE MUSCLES AND THE NERVES OF THE LUMBO-SACRAL PLEXUS.

margin of the iliac fossa; it has an additional origin also from the anterior sacro-iliac and ilio-lumbar ligaments. It is a fan-shaped muscle, its fibres passing downwards over the hip-joint towards the small trochanter of the femur. It is **inserted** (1) into the outer side of the tendon of the psoas; (2) into the concave anterior surface of the small trochanter; and (3), by its most external fibres, into the capsule of the hip-joint. These fibres are often separate, forming the **iliacus minor**, or **ilio-capsularis**. The muscle occupies the false pelvis and Scarpa's triangle. It forms the back wall of the false pelvis, covered anteriorly by the iliac fascia, and is

in contact with the cæcum on the right side and the iliac colon on the left side. The psoas muscle lies along its inner border, with the anterior crural nerve in the interval between them.

After passing beneath Poupart's ligament, and over the capsule of the hip-joint, the muscle occupies the outer part of Scarpa's triangle, internal to the sartorius and rectus femoris muscles.

The **pectineus arises** from the sharp anterior portion of the ilio-pectineal line of the pubis, and (sometimes) from the triangular surface of the pubic bone in front of this. Forming a broad muscular band, it is directed obliquely downwards, backwards and outwards, to be **inserted** into the upper half of the line leading from the small trochanter of the femur to the linea aspera; its lower attachment being placed in front of the insertion of the adductor brevis muscle.

The pectineus forms a part of the floor of Scarpa's triangle. Covered by the pubic portion of the fascia lata, it is partially concealed by the femoral vessels and the insertion of the ilio-psoas. It lies in front of the pubic bone, the obturator externus and adductor brevis muscles, and the superficial part of the obturator nerve. Its outer border is separated from the psoas by the internal circumflex artery. Its inner border is in contact above with the adductor longus: separated from it below by the deep femoral vessels. The muscle may be occasionally divided into inner and outer parts, the former innervated by the obturator, the latter by the anterior crural nerve.

THE MUSCLES ON THE INNER SIDE OF THE THIGH.

The muscles on the inner side of the thigh include the adductors of the femur—the adductor longus, adductor brevis, and adductor magnus: the gracilis, and the obturator externus.

The **gracilis muscle** is a long flat band placed on the inner side of the thigh and knee. It **arises** by a linear origin from the lower half of the edge of the symphysis pubis, and for a similar distance from the adjoining part of the pubic arch. Its flattened fleshy belly passes down on the inner side of the thigh to the knee, where it ends in a tendon, **inserted** into the inner side of the shaft of the tibia just below the inner tuberosity, behind the sartorius and above the semitendinosus. It is separated from the sartorius tendon by a bursa, and beneath its tendon is another bursa common to it and the semitendinosus.

The gracilis is superficial in its whole extent. Its deep surface covers the borders of the adductor longus and adductor magnus muscles, as well as the superficial part of the obturator nerve. At the inner side of the knee it lies between the sartorius and semitendinosus.

The **adductor longus** is a triangular muscle **arising** by a rounded tendon in the angle between the crest and symphysis of the pubis. Extending downwards and outwards, it is **inserted** into the middle two-fourths of the linea aspera. Lying in the same plane as the pectineus, the adductor longus is in contact with that muscle near its origin, but is separated from it below by an interval through which the deep femoral vessels pass. Its inner border is in contact with the gracilis and sartorius muscles. Its anterior surface forms part of the floor of Scarpa's triangle above, part of the floor of Hunter's canal below. It is covered near its insertion by the sartorius and the femoral vessels, and is connected to the origin of the vastus internus by an aponeurotic expansion of fascia beneath the sartorius, forming the roof of Hunter's canal. Its posterior surface is in relation with the adductor brevis and the adductor magnus muscles, the deep femoral vessels, and the superficial part of the obturator nerve. The adductor longus may be double, or more or less fused with the pectineus.

The **adductor brevis** is a large muscle which **arises** from the body of the pubis from an oval surface surrounded by the other muscles of this group. Directed downwards and outwards, the muscle expands, to be **inserted** by a linear attachment to the lower two-thirds of the line leading from the small

trochanter of the femur to the linea aspera, and to the upper fourth of the linea aspera itself.

The adductor brevis is the central muscle of the adductor group. It is almost wholly concealed by the pectineus and adductor longus. It rests upon the adductor magnus; at its upper border is the obturator externus, separated from it by the internal circumflex artery; at the lower border is the adductor longus, separated by the deep femoral artery. It separates the superficial and deep parts of the obturator nerve in their course down the thigh.

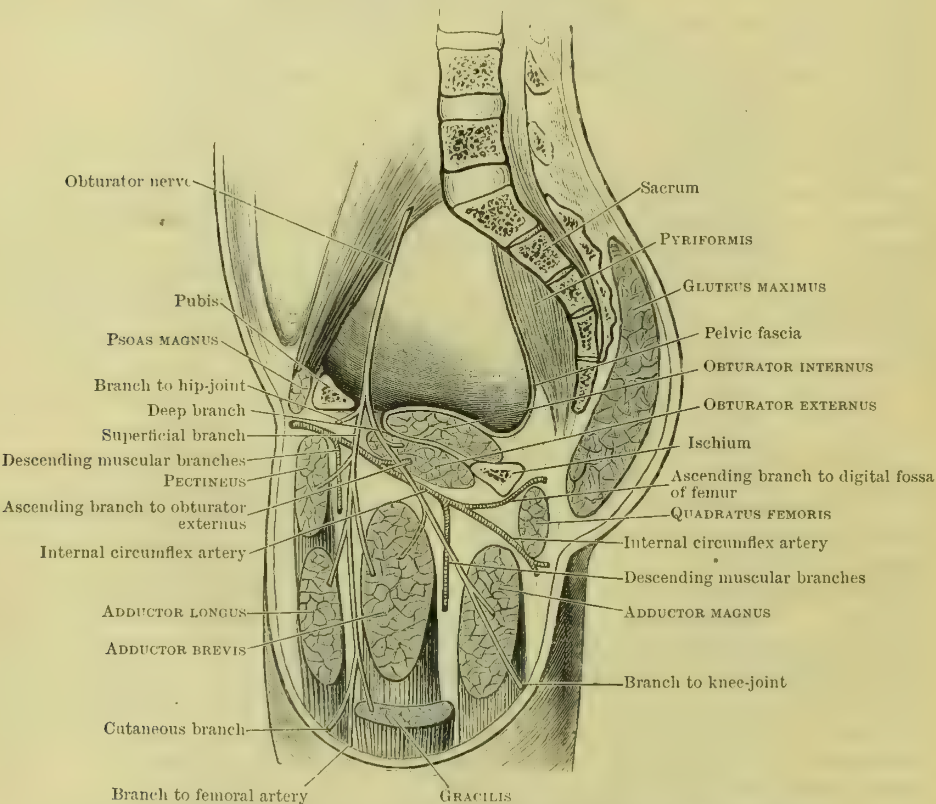


Fig. 254.—Scheme of the Course and Distribution of the Obturator Nerve.

The **adductor magnus**, the largest of the adductor group, is a roughly triangular muscle **arising** by a curved origin from the lower part of the outer border of the ischial tuberosity and the edge of the pubic arch, its most anterior fibres arising between the obturator externus and adductor brevis. Its upper fibres are directed horizontally outwards from the pubis towards the upper part of the femur; the lowest fibres are directed downwards from the ischial tuberosity to the internal condyle of the femur; while the intermediate fibres radiate obliquely outwards and downwards. The muscle is **inserted** (1) into the space below the insertion of the quadratus femoris, above the linea aspera; (2) into the whole length of the linea aspera; (3) into the internal supracondyloid ridge of the femur; and (4) into the internal condyle of the femur. The part of the muscle attached to the space above the linea aspera is often separated from the rest as the **adductor minimus.** The attachment of the muscle into the supracondyloid ridge is interrupted for the passage of the femoral vessels to the popliteal space. The attachment to the internal condyle is by means of a strong tendon which receives the fibres arising from the ischium (the part of the muscle associated with the hamstring group). This tendon is closely connected with the internal lateral ligament of the knee-joint.

The adductor magnus intervenes between the other adductor muscles in front and the hamstring muscles behind. It is concealed anteriorly by the pectineus,

adductor brevis, adductor longus, and sartorius. The deep femoral artery lies on it above. It forms the floor of Hunter's canal below, where the femoral vessels lie upon it. The hamstring muscles and great sciatic nerve are behind the adductor magnus; the obturator externus and quadratus femoris are at its upper border; and along its inner border are the gracilis and sartorius muscles.

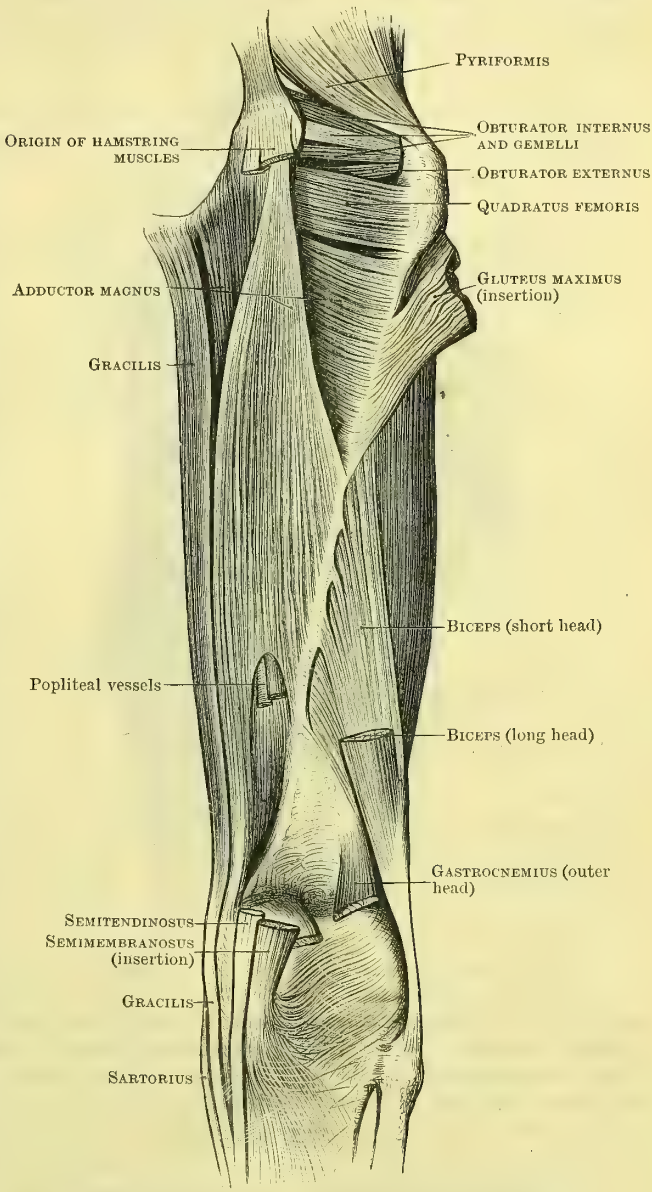


FIG. 255.—THE POSTERIOR SURFACE OF THE THIGH (superficial muscles removed).

The **obturator externus** is a fan-shaped muscle lying horizontally in the angle between the hip bone and the neck of the femur. It **arises** from the inferior half of the margin of the thyroid foramen and the corresponding portion of the outer surface of the obturator membrane. Its fibres converge towards the great trochanter, and end in a tendon which, after passing below and behind the hip-joint, is **inserted** into the digital fossa of the great trochanter. The inferior surface of the muscle is in contact with the pectineus, adductor brevis, and adductor magnus muscles, separated from them by the internal circumflex artery. The superior surface is in contact with the obturator membrane and the neck of the femur. The tendon lies below and behind the capsule of the hip-joint, and near its insertion appears in the buttock (beneath the gluteus maximus) between the inferior gemellus and quadratus femoris muscles.

THE MUSCLES OF THE BUTTOCK.

This group includes the three glutei muscles, the tensor fasciæ femoris pyriformis, obturator internus and gemelli, and quadratus femoris.

The **gluteus maximus** is a large quadrilateral muscle, with a crescentic **origin**, from (1) the dorsum ilii above the superior curved line; (2) the tendon of the erector spinæ; (3) the posterior surface of the sacrum and coccyx; and (4) the posterior surface of the great sacro-sciatic ligament. The fibres of the muscle are directed obliquely outwards over the buttock, invested by the fascia lata, and are **inserted** partly into the fascia lata over the great trochanter of the femur (joining

the ilio-tibial band), and partly into the gluteal ridge. The fascia lata receives the whole of the superficial fibres of the muscle and the upper half of the deep fibres. The lower half of the deep portion of the muscle is inserted for the most part into the gluteal ridge ; but the lowest fibres of all are inserted into fascia lata, and are thereby connected with the external intermuscular septum and the origin of the short head of the biceps.

The gluteus maximus is the coarsest and heaviest muscle in the body. By its weight it helps to form the fold of the nates. It is superficial in its whole extent. The gluteus medius is visible at its upper border, covered by the fascia lata; at its lower border the hamstring muscles and great sciatic nerve appear on their way down the thigh. The muscle conceals the bones from which it arises, along with the great sciatic ligament, the ischial tuberosity, and the great trochanter. It also conceals the gluteus medius and pyriformis, with a branch of the gluteal artery between them; the obturator internus and gemelli, with the sciatic vessels and nerves, the pudic vessels and nerves, and the muscular branches of the sacral plexus above them, and the obturator externus and a branch of the internal circumflex artery below them; the quadratus femoris and upper part of the adductor magnus, with the internal circumflex artery between them. It covers the origins of the hamstring muscles, and by its insertion into the fascia lata, the vastus externus. The first perforating artery pierces the attachment of the muscle to the gluteal ridge. Three bursæ are beneath it: one (not always present) over the tuberosity of the ischium, a second over the outer side of the great trochanter, and a third over the vastus externus. The fibres of the gluteus maximus arising from the coccyx may form a separate muscle (agitator caudæ).

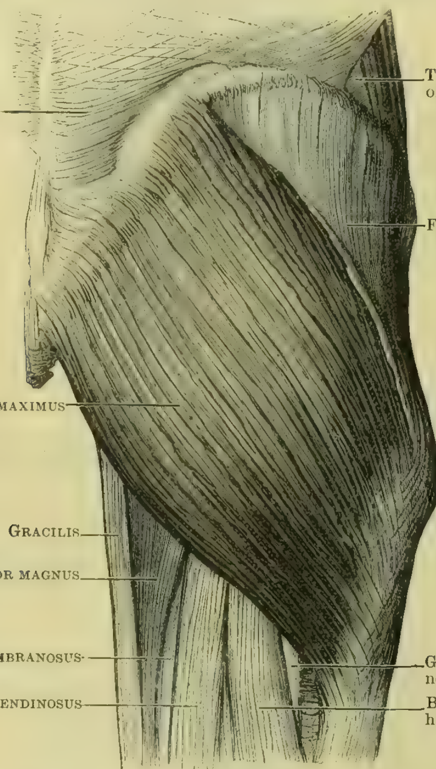


Fig. 256.—The Gluteus Maximus Muscle.

The **tensor fasciæ femoris** (m. tensor fasciæ latæ), lying on the same plane as the gluteus maximus, **arises** from the dorsum ilii external to the anterior superior spine and from the upper part of the notch below it. Invested like the gluteus maximus by the fascia lata, it is **inserted** about the level of the great trochanter of the femur into the fascia, forming the **ilio-tibial band.**

The tensor fasciæ femoris muscle is superficially placed, and is isolated in a strong investment of the fascia lata, the deeper layer of which is prolonged on to the tendon of the rectus femoris and the capsule of the hip-joint. The muscle is placed along the anterior borders of the gluteus medius and gluteus minimus, and conceals branches of the gluteal and external circumflex vessels and the termination of the superior gluteal nerve. The sartorius muscle is adjacent to it anteriorly at its origin, and is separated below by the rectus femoris.

The **gluteus medius arises** (1) from the dorsum ilii, between the iliac crest and the superior curved line above and the middle curved line below, and (2) from the strong fascia lata covering its surface anteriorly. It is a fan-shaped

muscle, its fibres converging to the great trochanter, to be **inserted** by a strong short tendon into a diagonal line on its outer surface.

The muscle is covered along its anterior border by the tensor fasciæ femoris. Its surface is covered over by the fascia lata and the gluteus maximus. Its inferior border is separated from the pyriformis muscle by the superficial branch of the gluteal artery. Its deep surface is in contact with the gluteus minimus, the gluteal vessels, the superior gluteal nerve, and the insertion of the pyriformis. A bursa is placed beneath the tendon at its insertion.

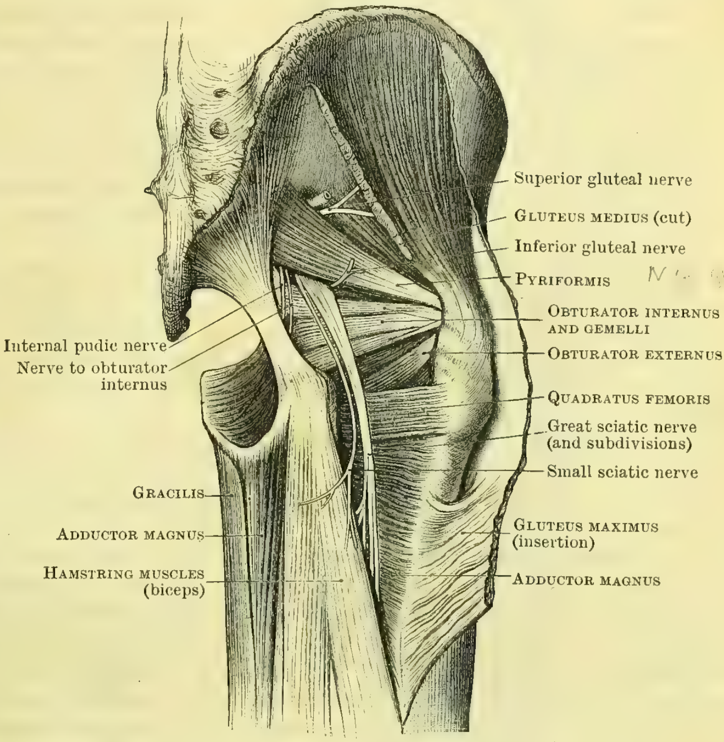


Fig. 257.—The Muscles and Nerves of the Buttock.
The gluteus maximus is reflected; and the gluteus medius is cut in part to show the gluteus minimus.

The **gluteus minimus arises** from the dorsum ilii between the middle and inferior curved lines. This muscle is fan-shaped, and its fibres converge to the antero-superior angle of the great trochanter, to be **inserted** into the outer border of the anterior surface of the trochanter, and sometimes also into the front part of the upper border. It is also inserted into the capsule of the hip-joint. The muscle is concealed by the tensor fasciæ femoris and gluteus medius. The pyriformis is in contact with its inferior border, and beneath it are the capsule of the hip-joint and the reflected tendon of the rectus femoris muscle. A bursa is placed beneath the tendon in front of the great trochanter.

The **pyriformis** is one of the few muscles connecting the lower limb to the axial skeleton. It **arises** (1) within the pelvis from the pedicles of the second, third, and fourth sacral vertebræ; passing outwards through the great sacro-sciatic foramen, it receives an additional origin (2) from the upper margin of the great sciatic notch of the ilium. In the buttock it forms a rounded tendon, which is **inserted** into a facet on the upper border of the great trochanter of the femur.

The pyriformis, besides appearing in the buttock, lines the posterior wall of the pelvis. In the pelvis it lies behind the rectum, covered by a thin layer of the parietal pelvic fascia. In the buttock it is covered by the gluteus maximus, and at its insertion by the gluteus medius, and it lies upon the ilium and the capsule of the hip-joint. At its upper border are the gluteus medius and gluteus minimus, separated by the superior gluteal nerve and the gluteal artery; its lower border is separated from the gemelli and obturator internus by an interval in which the sciatic and pudic vessels and the nerves of the sacral plexus appear. The anterior fibres of the muscle may be separate (scansorius).

The **obturator internus arises** on the pelvic aspect of the hip bone, from (1) the whole of the margin of the thyroid foramen (except the obturator notch); (2) the surface of the obturator membrane; (3) from the smooth surface of the hip bone behind the thyroid foramen; and (4) slightly from the parietal pelvic fascia covering

it internally. It is a fan-shaped muscle, the fibres of which, converging to the lesser sacro-sciatic foramen, give rise to several tendons which hook round the margin of the foramen (a bursa intervening), and after traversing the buttock, unite together to be **inserted** into a facet on the inner surface of the great trochanter of the femur above the digital fossa.

In the pelvis the muscle occupies the lateral wall, covered by the parietal (obturator) layer of pelvic fascia, which separates it from the pelvic cavity above and the ischio-rectal fossa below. It is separated from the contents of the pelvis, above by the peritoneum and extra-peritoneal fat, below by the fat in the ischio-rectal fossa. The internal pudic vessels and nerve cross it in the outer wall of the fossa in a special sheath of the fascia. In the buttock the tendon is embraced by the gemelli muscles which are attached to its upper and lower margins. The tendon is crossed by the sciatic vessels and nerves, and lies upon the upper and back part of the capsule of the hip joint.

The **gemelli muscles** form accessory portions of the obturator internus. They are two in number, **superior** and **inferior**.

The **superior gemellus arises** from the gluteal surface of the ischial spine and from the upper part of the margin of the lesser sciatic notch. It is **inserted** into the upper margin and superficial surface of the tendon of the obturator internus muscle.

The **gemellus inferior arises** from the upper part of the gluteal surface of the ischial tuberosity and the lower part of the margin of the lesser sciatic notch. It is **inserted** into the lower margin and superficial aspect of the tendon of the obturator internus.

The **quadratus femoris arises** from the outer margin of the ischial tuberosity, and is **inserted** into the quadrate line of the femur. The muscle is placed beneath the gluteus maximus, and is crossed by the sciatic vessels and nerves. Its origin is concealed by the hamstring muscles. Its deep surface is in contact with the obturator externus muscle and the small trochanter of the femur, a bursa intervening. Its upper border is separated from the inferior gemellus by an interval, containing the tendon of the obturator externus and the ascending branch of the internal circumflex artery. Its lower border is separated from the upper margin of the adductor magnus by the internal circumflex artery. The muscle is not infrequently fused with the adductor magnus.

THE MUSCLES ON THE BACK OF THE THIGH.

The Hamstring Muscles.

The muscles comprised in this series include the biceps, semitendinosus and semimembranosus. A part of the adductor magnus, already described, belongs morphologically to this group.

The **biceps flexor cruris** (m. biceps femoris) has a double **origin.** (1) *Its long head* arises, in common with the semitendinosus, from the lower and inner facet upon the ischial tuberosity and from the great sacro-sciatic ligament. This head, after a union of two to three inches with the semitendinosus, forms a separate fleshy mass, which extends to the lower third of the thigh, to end in a tendon, joined by the short head of the muscle. (2) *The short head* arises separately (1) from the whole length of the linea aspera and the upper two-thirds of the external supracondyloid ridge of the femur, and (2) from the external intermuscular septum for a corresponding extent. The upper limit of its origin is sometimes blended with the insertion of the lowest fibres of the gluteus maximus. The fibres of the short head, directed downwards, join the tendon of the long head, and the muscle is **inserted** (1) into the head of the fibula by a strong tendon, split into two parts by the long external lateral ligament of the knee-joint, and (2) along its posterior border, by transverse aponeurotic fibres which connect the tendon with the popliteal fascia.

At its origin the long head of the biceps is concealed by the gluteus maximus. In the lower two-thirds of the thigh it is superficially placed, with the semitendinosus and semimembranosus on its inner side. It conceals the great sciatic nerve,

the origins of the semimembranosus and quadratus femoris, the adductor magnus, and the short head of the muscle. The united heads assist in forming the outer boundary of the popliteal space, and partially conceal the outer head of the gastrocnemius.

The short head may be absent: there may be an additional origin from ischium or femur; and the long head may send a slip to the gastrocnemius or tendo Achillis (tensor fasciæ suralis).

The **semitendinosus arises**, in common with the long head of the biceps, from the lower and inner facet upon the ischial tuberosity. Separating from the common tendon after a course of two or three inches, the muscle forms a long narrow band which becomes tendinous in the middle third of the thigh. Passing over the inner side of the knee, it spreads out and becomes membranous, and is **inserted** into the inner side of the shaft of the tibia just below the internal tuberosity, below the gracilis and behind the sartorius. A bursa separates it from the sartorius in front, and another, common to it and the gracilis, lies beneath its insertion.

The origin of the muscle is concealed by the gluteus maximus. In the back of the thigh it is superficial to the semimembranosus; and at the inner side of the knee the tendon lies behind that of the gracilis. It forms one of the inner boundaries of the popliteal space. The belly of the muscle is marked by an oblique septal intersection about its middle.

The **semimembranosus arises** by a tendon from the upper and outer facet on the ischial tuberosity. In the upper third of the thigh the tendon gives place to a rounded fleshy belly, which, becoming tendinous at the back of the knee, is **inserted** mainly into the horizontal groove on the back of the inner tuberosity of the tibia. A bursa lies beneath the tendon at its insertion. It has three *additional membranous insertions:* (1) a fascial band extends downwards and inwards to join the posterior border of the internal lateral ligament of the knee-joint; (2) another fascial band extends downwards and outwards, forms the fascia covering the popliteus muscle, and is attached to the oblique line of the tibia; and (3) another band extends upwards and outwards to the back of the external condyle of the femur, forming the posterior ligament of the knee-joint.

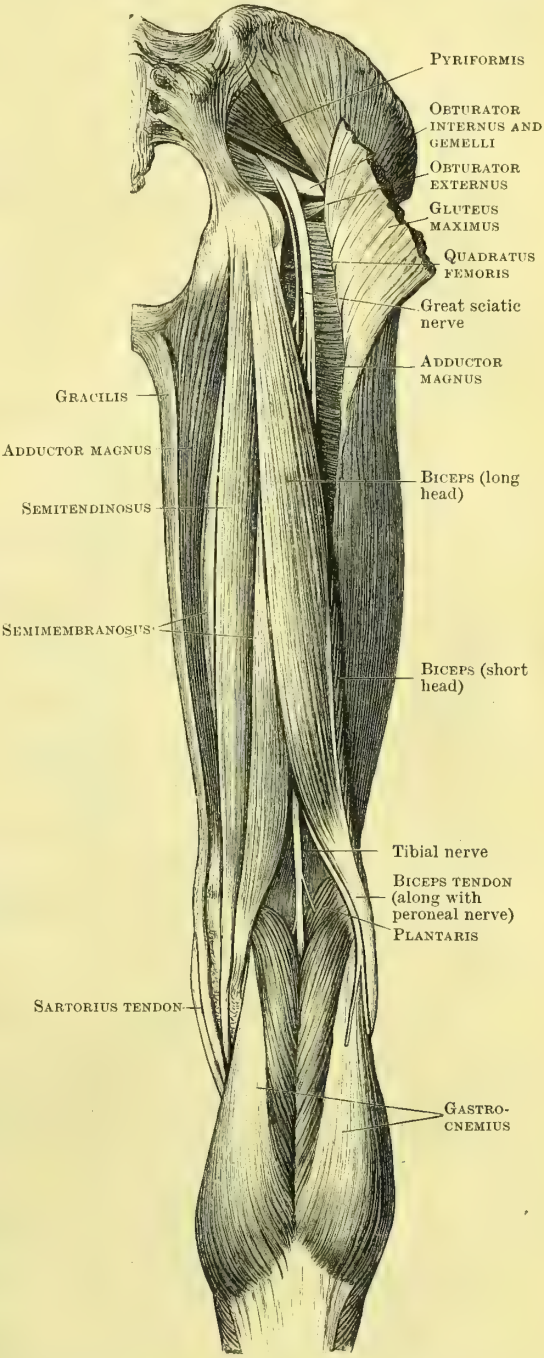


FIG. 258.—THE MUSCLES ON THE BACK OF THE THIGH.

The tendon of origin is concealed by the gluteus maximus, and immediately beyond the ischium it is grooved by the common origin of the long head of the biceps and semitendinosus. In the back of the thigh it is covered by the semitendinosus, and lies upon the adductor magnus and great sciatic nerve. It forms part of the inner boundary of the popliteal space, and conceals the popliteal vessels. Its tendon passes over the inner head of the gastrocnemius on its way to its insertion.

Nerve Supply of the Muscles of the Thigh and Buttock.

The innervation of the muscles described above is given in the following table :—

Muscles.	Nerves.	Origin.
Pectineus	Anterior crural	L. 2. 3.
Sartorius	Anterior crural	L. 2. 3.
Iliacus	Anterior crural	L. 2. 3. 4.
Psoas	Anterior crural	L. 2. 3. 4.
Quadriceps extensor	Anterior crural	L. 3. 4.
Vastus externus, Rectus femoris, Crureus, Vastus internus	Anterior crural	L. 3. 4.
Tensor fasciæ femoris	Superior gluteal	L. 4. 5. S. 1.
Gluteus minimus	Superior gluteal	L. 4. 5. S. 1.
Gluteus medius	Superior gluteal	L. 4. 5. S. 1.
Gluteus maximus	Inferior gluteal	L. 5. S. 1. 2.
Biceps (short head)	Peroneal	L. 5. S. 1. 2.
Pyriformis	Sacral plexus	S. 1. 2.
Adductor longus	Obturator	L. 2. 3.
Gracilis	Obturator	L. 2. 3. 4.
Adductor brevis	Obturator	L. 3. 4.
Obturator externus	Obturator	L. 3. 4.
Adductor magnus	Obturator	L. 3. 4.
	Nerve to hamstrings	L. 4. 5. S. 1.
Semimembranosus	Nerve to hamstrings	L. 4. 5. S. 1.
Semitendinosus	Nerve to hamstrings	L. 5. S. 1. 2.
Biceps (long head)	Nerve to hamstrings	S. 1. 2. 3.
Quadratus femoris and inferior gemellus	Sacral plexus	L. 4. 5. S. 1.
Superior gemellus and obturator internus	Sacral plexus	S. 1. 2. 3.

Action of the Muscles of the Thigh and Buttock.

Most of the above muscles act on the pelvis and on the hip- and knee-joints. The psoas muscle acts in addition on the vertebral column.

1. **Movements at the Hip-Joint.**—The movements of the thigh at the hip-joint are flexion and extension, adduction and abduction, internal and external rotation. The following table gives the muscles producing these movements :—

a. **Flexion**	and **Extension.**
Sartorius	Gluteus maximus
Iliacus	„ medius
Psoas	„ minimus
Rectus femoris	Biceps
Pectineus	Semitendinosus
Adductor longus	Semimembranosus
Gracilis	Adductor magnus
Obturator externus	

b. **Adduction** and	**Abduction.**
Pectineus Adductor longus „ brevis „ magnus Gracilis Quadratus femoris Gluteus maximus (lower fibres)	Tensor fasciæ femoris Gluteus medius Gluteus minimus Obturator externus Pyriformis, Obturator internus, Gemelli, Sartorius, Gluteus maximus (upper fibres) } during flexion

c. **Internal Rotation** and	**External Rotation.**
Tensor fasciæ femoris Gluteus medius (anterior fibres) „ minimus „ „	Obturator externus Gluteus maximus (lower fibres) Quadratus femoris Gluteus medius, „ minimus } (posterior fibres) Pyriformis, Obturator internus, Gemelli } during extension Sartorius Ilio-psoas Pectineus Adductor longus „ brevis „ magnus Biceps

2. **Movements of the Pelvis on the Thigh.**—It is to be noted that the several movements tabulated above refer to the movements of the femur at the hip-joint. The contraction of the same groups of muscles produces similar movements of the pelvis on the femur, exemplified in the various changes in the attitude of the pelvis in relation to the thigh and the vertebral column, which occur in locomotion.

3. **Movements at the Knee-Joint.**—The movements at the knee-joint are mainly flexion and extension. Flexion is much more powerful than extension. There is also a limited amount of rotation of the tibia. The movements are produced by certain of the muscles described above, associated with certain of the muscles of the leg.

a. **Flexion** and	**Extension.**	*b.* **Rotation inwards** and	**Rotation outwards.**
Sartorius Gracilis Semitendinosus Semimembranosus Biceps Gastrocnemius Plantaris Popliteus	Quadriceps extensor	Sartorius Gracilis Semitendinosus Semimembranosus Popliteus	Biceps flexor cruris

THE FASCIÆ AND MUSCLES OF THE LEG AND FOOT.

FASCIÆ.

The **superficial fascia** of the leg presents no special features except in the sole, where it is greatly thickened by pads of fat, particularly under the tuberosity of the os calcis, and under the balls of the toes. It is closely adherent to the plantar fascia, especially at the roots of the toes.

The **deep fascia** has numerous important attachments about the knee. Posteriorly it forms the popliteal fascia. In front of the knee it is attached to the patella, the ligamentum patellæ, and the tubercle of the tibia; laterally it is connected to the tuberosities of the tibia and the head of the fibula, and forms the

lateral patellar ligaments. Passing down the leg, the fascia blends over the inner surface of the tibia with the periosteum of the bone. It extends round the outer side of the leg from the anterior to the internal border of the tibia, binding together and giving origin to the muscles, and gaining an attachment to the lower part of the shaft of the fibula. **Two septa** pass from its deep surface; one septum is attached to the anterior border of the fibula, encloses the musculo-cutaneous nerve, and separates the extensor from the peronei muscles. The other septum is attached to the posterior border of the fibula, and separates the peronei from the flexor muscles. From the last-named septum another extends across the back of the leg, forms a partition between the superficial and deep flexor muscles, and encloses the posterior tibial vessels and nerves. It gives rise to subordinate septa attached to the vertical line of the tibia and the oblique line of the fibula, which separate the tibialis posticus muscle from the flexors of the toes on either side.

At the ankle the deep fascia is strengthened by additional transverse fibres; it is attached to the malleoli and the os calcis, and gives rise to the **annular ligaments.**

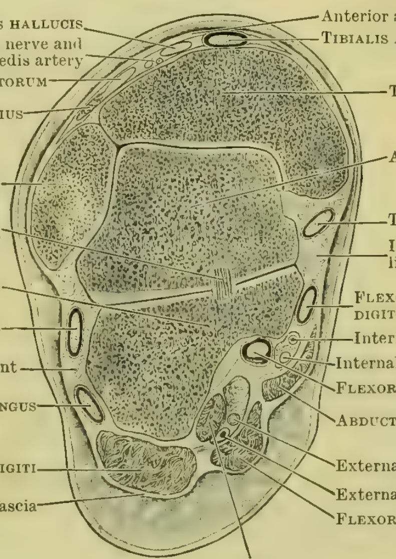


Fig. 259.—Coronal Section through the left Ankle Joint, Astragalus, and Calcaneum.

The **internal annular ligament** stretches between the internal malleolus and the tuberosity of the os calcis. While it is continuous at its upper border with the general investment of the deep fascia of the leg, it is chiefly formed by the septal layer covering the deep muscles on the back of the leg. It sometimes gives insertion to the plantaris muscle. It is continuous below with the plantar fascia, and gives origin to the abductor hallucis muscle. It is pierced by the calcanean vessels and nerve. Along with the posterior tibial vessels and nerve, the tendons of the tibialis posticus, flexor longus digitorum, and flexor longus hallucis, pass beneath it, each enclosed in a separate synovial sheath.

The **external annular ligament**, much smaller, is a thickened band of the deep fascia stretching between the external malleolus and the os calcis. It binds down the tendons of the peronei, which occupy a space beneath the ligament, lined by a single synovial membrane.

The **anterior annular ligament** is in two parts. An **upper band**, broad and undefined at its upper and lower borders, stretches across the front of the ankle between the two malleoli. This band binds down to the lower end of the tibia the tendons of the tibialis anticus and extensor muscles of the toes. One synovial sheath is found beneath it, surrounding the tendon of the tibialis anticus.

On the dorsum of the foot, where the general covering of deep fascia is much thinner, a special well-defined band stretches over the extensor tendons. This **lower band** of the anterior annular ligament (fundiform or lambdoid ligament) has an attachment externally to the greater process of the os calcis. It divides into two bands as it passes inwards over the dorsum of the foot—an *upper part*, which joins the upper ligament and is attached to the internal malleolus, and a

lower part, which passes across the dorsum of the foot, and joins the fascia of the sole at its inner border. Beneath this ligament are three special compartments with separate synovial sacs, one for the tibialis anticus tendon, a second for that of the extensor proprius hallucis, and a third for the extensor longus digitorum and peroneus tertius tendons. There are occasionally other additional bands of the deep fascia passing like the straps of a sandal across the dorsum of the foot.

The **plantar fascia** is of great importance. In the centre of the sole it forms a thick triangular band, attached posteriorly to the tuberosity of the os calcis. It spreads out anteriorly and separates into *five slips,* which are directed forwards to the bases of the toes. These slips as they separate are joined together by ill-defined bands of transverse fibres, which constitute the **superficial transverse metatarsal ligament.** The slip for each toe joins the tissue of the web of the toe and is continuous with the digital sheath. On each side of the toe a band of fibres is directed forwards, to be attached to the side of the metatarso-phalangeal articulation and the base of the first phalanx.

This central portion of the plantar fascia assists in preserving the arch of the foot, by drawing the toes and the os calcis together.

On each side it is continuous with a much thinner layer which covers the lateral muscles of the sole, and joins the fascia of the dorsum of the foot at each border. It also gives rise to intermuscular septa, which pass upwards on each side of the flexor brevis digitorum, enclosing that muscle in a separate sheath, and giving investments on either side to the abductor muscles of the great and little toes. At the outer border of the foot, the **calcaneo-metatarsal ligament**, a thickened band of the fascia, connects the tuberosity of the os calcis with the base of the fifth metatarsal bone.

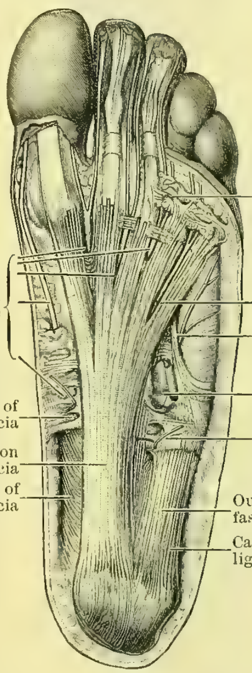


Fig. 260.—The Plantar Fascia and Plantar Cutaneous Nerves.

The **digital sheaths**, though smaller, are the same in arrangement as those of the fingers. **Vaginal ligaments** are present in relation to the first and second phalanges.

THE MUSCLES OF THE LEG AND FOOT.

The muscles of the leg and foot are divisible into three series: (1) the extensor muscles on the front of the leg and dorsum of the foot; (2) the peronei on the outer side of the leg; and (3) the flexor muscles on the back of the leg and in the sole of the foot.

The Muscles on the Front of the Leg and Dorsum of the Foot.

The muscles on the front of the leg and dorsum of the foot include two groups: (1) on the front of the leg, the tibialis anticus, long extensors of the toes and peroneus tertius; and (2) on the dorsum of the foot, the extensor brevis digitorum.

The **tibialis anticus** (m. tibialis anterior) **arises** from the upper two-thirds of the outer surface of the tibia, from the interosseous membrane, from the fascia over it, and from an intermuscular septum externally. The muscle ends in

a strong tendon which passes over the dorsum of the foot, to be **inserted** into the internal cuneiform and the base of the first metatarsal bone.

The muscle is superficially placed along the outer side and front of the tibia, internal to the long extensors of the toes and the anterior tibial vessels and nerve. Its tendon occupies special compartments beneath both upper and lower parts of the anterior annular ligament, enclosed in a separate synovial sac.

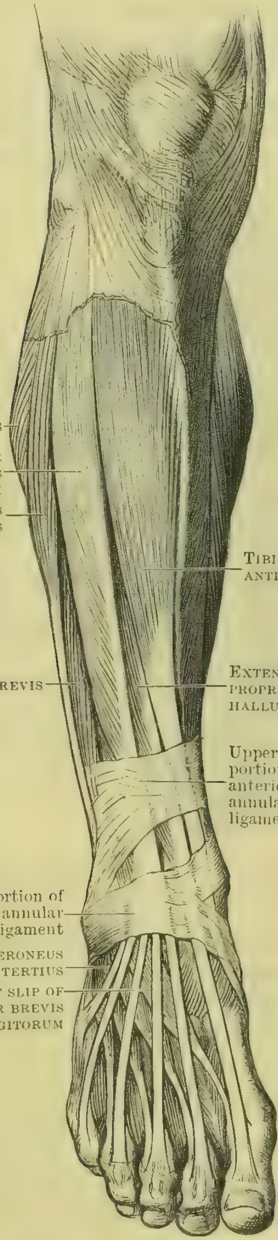


Fig. 261.—Muscles of the Front of the Right Leg and Dorsum of the Foot.

The **tibio-fascialis anticus** is a separated portion of the muscle occasionally present, inserted into the fascia on the dorsum of the foot.

The **extensor longus digitorum arises** from the outer side of the external tuberosity of the tibia, from the upper two-thirds or more of the anterior surface of the fibula, from the fascia over it, and from intermuscular septa on either side. It gives rise to a tendon which passes beneath the anterior annular ligament, and in front of the ankle divides into four tendons, **inserted** into the four outer toes, exactly in the same way as the corresponding tendons in the hand (see p. 330). They form membranous expansions on the dorsum of the first phalanx, joined by the tendons of the extensor brevis digitorum, lumbricales, and interossei, which separate into one central and two lateral slips, attached respectively to the middle and terminal phalanges.

The muscle is superficial, and is placed external to the tibialis anticus and extensor proprius hallucis, and internal to the peronei muscles. The musculo-cutaneous nerve is on its outer side. It conceals the anterior tibial vessels and nerve. The tendon occupies a separate compartment along with the peroneus tertius beneath the lower part of the anterior annular ligament, invested by a special synovial membrane.

The **peroneus tertius** is a separated portion of the extensor longus digitorum. It is an essentially human muscle. It **arises** (inseparably from the extensor longus digitorum) from the anterior surface of the fibula, and from the intermuscular septum external to it. The tendon of the muscle is **inserted** into the dorsal aspect of the base of the fifth metatarsal bone. It accompanies the extensor longus digitorum beneath the anterior annular ligament, and lies external to that muscle on the dorsum of the foot.

The **extensor proprius hallucis muscle** (m. extensor hallucis longus) **arises** from the front of the fibula in its middle three-fifths, and for a corresponding extent from the interosseous membrane. Its tendon passes over the dorsum of the foot, to be **inserted** into the base of the terminal phalanx of the great toe. In the leg the muscle is deeply placed between the tibialis anticus and extensor longus digitorum. It conceals the anterior tibial vessels and nerve, and crosses the termination of the anterior tibial artery in front of the ankle joint. It is invested by a special synovial sac as it lies beneath the

lower part of the anterior annular ligament. On the dorsum of the foot the tendon is placed on the inner side of the dorsalis pedis artery.

The **extensor longus primi internodii** and **extensor ossis metatarsi hallucis** are occasional separate slips of this muscle inserted into the bones of the great toe.

The **extensor brevis digitorum arises** on the dorsum of the foot from a special impression on the upper surface of the greater process of the os calcis.

It usually gives rise to four fleshy bellies, from which narrow tendons are directed forwards and inwards, to be **inserted** into the four inner toes. The three outer tendons join those of the long extensor muscle to form the membranous expansions on the dorsum of the toes. The *innermost tendon* is inserted separately into the base of the first phalanx of the great toe.

The muscle is covered by the lower band of the anterior annular ligament, and by the tendons of the extensor longus digitorum and peroneus tertius; the slip of the muscle passing to the great toe crosses the dorsalis pedis artery.

The Muscles on the Outer Side of the Leg.

The muscles on the outer side of the leg comprise the peronei—longus and brevis.

The **peroneus longus arises** from the upper two-thirds of the outer surface of the fibula, from intermuscular septa on either side, and from the fascia over it. It forms a stout tendon, which hooks round the external malleolus, crosses the outer side of the os calcis, and passing through the groove on the cuboid bone, is directed across the sole of the foot, to be **inserted** into the internal cuneiform and the base of the first metatarsal bones. The muscle is placed superficially in the leg, between the extensor longus digitorum and peroneus brevis in front and the soleus and flexor longus hallucis behind. It partially conceals the peroneus brevis, along with which it passes beneath the external annular ligament, invested by a common synovial sheath. As it enters the sole of the foot a *fibro-cartilage* is formed in the tendon, which plays over a smooth tubercle on the cuboid bone, a bursa intervening. In its passage across the foot the tendon is enclosed in a fibrous sheath derived from the inferior calcaneo-cuboid ligaments and the tibialis posticus tendon, and is concealed by the first three layers of the muscles of the sole.

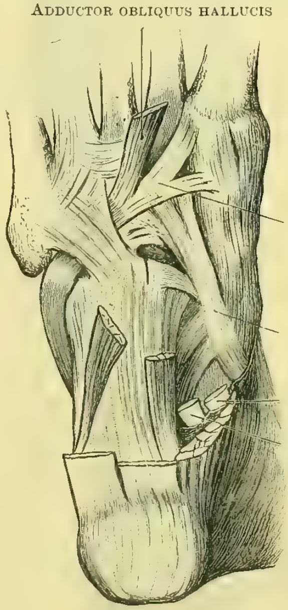


Fig. 262.—The Insertions of the Peroneus Longus and Tibialis Posticus Muscles in the Sole of the Right Foot.

The **peroneus brevis arises** from the lower two-thirds of the outer surface of the fibula, and from an intermuscular septum along its anterior border. Its tendon passes over the back of the external malleolus and the outer side of the os calcis, to be **inserted** into the base of the fifth metatarsal bone. In the leg the peroneus brevis lies behind the extensor longus digitorum and peroneus tertius, and in front of the peroneus longus, which partially overlaps it. The tendon lies directly behind the external malleolus beneath the external annular ligament, invested by a synovial sheath common to it and the peroneus longus.

The peroneus longus and brevis may be fused together, or additional slips may be present, as **peroneus accessorius, peroneus quinti digiti, peroneo-calcaneus externus,** and **peroneo-cuboideus.**

The Muscles on the Back of the Leg.

The muscles on the back of the leg are divisible into two layers: (1) a **superficial set,** consisting of the gastrocnemius and soleus (the so-called triceps

muscle of the leg), and the plantaris; and (2) a **deep set**, consisting of the popliteus, flexor longus digitorum, tibialis posticus, and flexor longus hallucis.

The **gastrocnemius arises** by *two heads*, inner and outer, by means of strong tendons (prolonged over the surface of the muscle) from the lateral surface of each condyle of the femur and from the back of the capsule of the knee-joint. A bursa lies beneath each tendon of origin. Each fleshy belly of the muscle is **inserted** into a broad membranous tendon, prolonged upwards on its deep surface for some distance. The inner head is the larger.

FIG. 263.—THE SOLEUS MUSCLE.

The **tendo Achillis** is formed by the union of the two membranous insertions of the bellies of the gastrocnemius. Prolonged upwards beneath the separate bellies, the tendon forms a broad membranous band connecting together the lower parts of the two bellies. Narrowing gradually, and becoming thicker in the lower half of the leg, the tendon is finally **inserted** into the lower half of the posterior surface of the os calcis. A bursa lies beneath the tendon at its insertion. The tendo Achillis also affords insertion to the soleus and (sometimes) the plantaris muscles.

The gastrocnemius is superficial except at its origin. The inner head is concealed by the semitendinosus and semimembranosus muscles, and covers partially the lower part of the popliteal vessels and the tibial nerve. It forms part of the inner boundary of the popliteal space. The outer head is concealed partially by the biceps tendon and the peroneal nerve, and covers the plantaris muscle, the popliteal vessels, and the tibial nerve. It forms part of the outer boundary of the popliteal space. The two bellies are for the most part in close contact, the external saphenous vein occupying the interval between them. The tendo Achillis in the lower half of the leg partially conceals the soleus and the deeper muscles. The plantaris tendon lies along its inner border.

The **plantaris arises** from the external supra-condyloid ridge of the femur for about an inch at its lower end, and from the posterior ligament of the knee-joint. It forms a narrow fleshy slip which ends in a tendon extending down the back of the leg, to be **inserted** into the tuberosity of the os calcis, or the tendo Achillis, or the internal annular ligament. The tendon of the muscle is capable of considerable lateral extension. The plantaris lies between the outer head of the gastrocnemius and the soleus, and crosses the popliteal vessels and the tibial nerve. In the lower half of the leg its tendon lies along the inner border of the tendo Achillis. The muscle is not always present.

The **soleus** has a triple **origin**: (1) from the posterior surface of the head and the shaft of the fibula in its upper third; (2) from a fibrous arch stretching over

the popliteal vessels and tibial nerve between the tibia and fibula; and (3) from the oblique line and middle third of the inner border of the tibia. From this origin the upper muscular fibres are directed downwards to join a tendon placed on the superficial aspect of the muscle, which is **inserted** into the tendo Achillis; the lower fibres are inserted directly into the tendo Achillis to within one or two inches of the os calcis.

The muscle is concealed by the gastrocnemius, plantaris, and tendo Achillis in nearly its whole extent. It is partially superficial on each side of the gastrocnemius and tendo Achillis. The muscle covers the tibialis posticus and the flexor muscles of the toes as well as the posterior tibial vessels and nerve.

The **deep muscles** of the back of the leg comprise the popliteus, the long flexors of the toes, and the tibialis posticus.

The **popliteus** is deeply placed behind the knee. It **arises** by a stout tendon from a rough impression in front of a groove on the outer aspect of the external condyle of the femur. This tendon passes between the external semilunar cartilage and the capsule of the knee-joint, and pierces the posterior ligament, from which it takes an additional origin. A bursa is placed beneath the tendon which communicates usually with the synovial cavity of the knee-joint. The muscle is **inserted** (1) into a triangular surface on the back of the tibia above the oblique line, and (2) into the fascia over it (the popliteus fascia, derived from the tendon of the semimembranosus muscle). The popliteus is covered at its origin by the capsule of the knee-joint. Posteriorly it is concealed by the gastrocnemius and plantaris muscles, and by the popliteal vessels and tibial nerve. Its lower border corresponds to the point of bifurcation of the popliteal artery and the origin of the soleus muscle.

The **popliteus minor** is a small muscle attached to the popliteal space of the femur and the posterior ligament of the knee-joint.

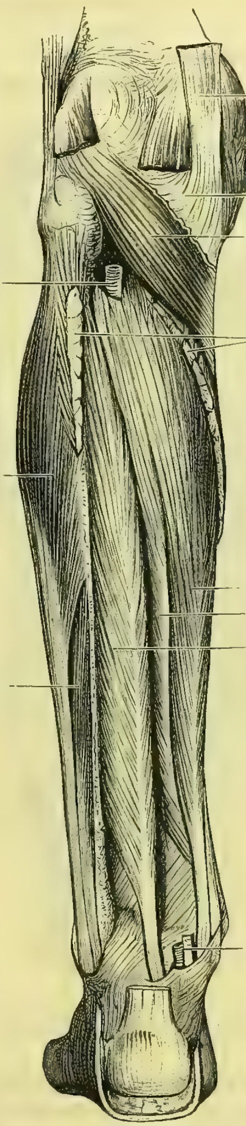


FIG. 264.—THE DEEP MUSCLES ON THE BACK OF THE LEFT LEG.

The **flexor longus digitorum** occupies both the back of the leg and the sole of the foot. Its **origin** is from the posterior surface of the tibia in its middle two-fourths, from the fascia over it, and from an intermuscular septa on each side. Its tendon, after passing beneath the internal annular ligament, enters the sole of the foot, and divides into four subordinate tendons, which are **inserted** into the four outer toes in precisely the same manner as the flexor profundus digitorum in the hand. Each tendon enters the digital sheath of the toe, perforates the tendon of the flexor brevis digitorum, and is inserted into the base of the terminal phalanx. **Ligamenta accessoria** (**longa** and **brevia**) are present as in the hand. Associated with this muscle in the sole of the foot are the lumbricales and accessorius.

The **lumbricales** are four small muscles **arising** in association with the tendons of the flexor profundus digitorum in the sole. The *first muscle* arises by a single origin from the tibial side of the tendon of the flexor longus digitorum for the second toe; the *other three* arise by two heads from the adjacent sides of all four tendons. Each muscle is **inserted** into the dorsal expansion of the extensor tendon, the metacarpo-phalangeal articulation, and the base of the first phalanx, precisely as in the case of the lumbrical muscles of the hand. Each muscle passes forwards on the tibial side of the corresponding toe, superficial to the transverse metatarsal ligament.

The **accessorius muscle** (m. quadratus plantæ) **arises** by two heads: (1) the outer tendinous head springs from the outer border of the inferior surface of the os calcis; (2) the inner head, which is fleshy, arises from the inner border of the under surface of the os calcis. The long plantar ligament separates the two origins. The two heads unite to form a flattened band, which is **inserted** into the upper aspect of the tendons of the flexor longus digitorum, and usually into the tendons destined for the second, third, and fourth toes.

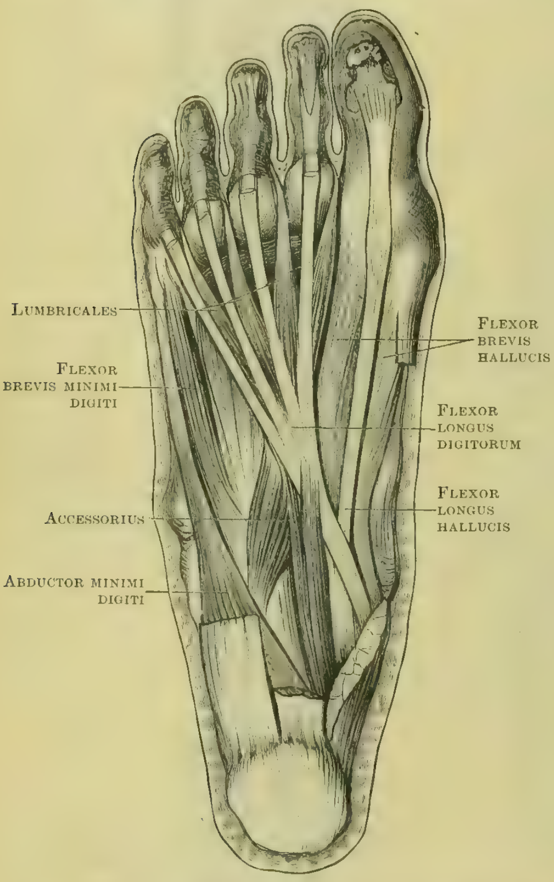


FIG. 265.—THE MUSCLES OF THE RIGHT FOOT (after removal of the first layer).

In the leg the flexor longus digitorum lies at first internal to the tibialis posticus, and is partially concealed by the soleus and tendo Achillis. Its tendon crosses over the tibialis posticus above the ankle, passes beneath the internal annular ligament, invested by a special synovial sheath, and below the ligament crosses the plantar or superficial surface of the tendon of the flexor longus hallucis. As it passes over this tendon it receives from it a special band of fibres usually associated with the tendons for the second and third toes.

In the sole of the foot the tendons of the flexor longus digitorum, along with the lumbricales and accessorius, and the flexor longus hallucis, constitute the second layer of muscles of the sole. They are placed between the abductors of the great and little toes and the flexor brevis digitorum on the one hand, and the flexor brevis and adductors of the great toe on the other.

The **flexor longus hallucis** **arises** on the back of the leg from the lower two-thirds of the posterior surface of the fibula, from the fascia over it, and from intermuscular septa on either side. Its tendon passes beneath the internal annular ligament enclosed in a special synovial sheath, and after grooving the back of the lower end of the tibia, the astragalus, and the under surface of the sustentaculum tali of the os calcis, it is directed forwards in the sole of the foot, to be **inserted** into the base of the terminal phalanx of the great toe.

The muscle is partially concealed in the leg by the soleus and tendo Achillis. It lies at its origin between the tibialis posticus and the peronei muscles, separated from the former by the peroneal artery. In the foot, concealed by the abductor hallucis, it crosses over the deep aspect of the tendon of the flexor longus

digitorum, to which it is connected by a strong fibrous band destined for the tendons for the second and third toes. At the root of the great toe the tendon occupies the interval between the insertions of the flexor brevis hallucis.

The **tibialis posticus muscle** (m. tibialis posterior) has a fourfold **origin** in the leg. It arises (1) from the middle three-fifths of the shaft of the fibula between the oblique line and the interosseous border; (2) from the middle third of the back of the tibia between the vertical line and the interosseous border; (3) from the interosseous membrane; and (4) from the fascia over it and the septa on either side. The muscle gives rise to a strong tendon which passes beneath the internal annular ligament, invested by a special synovial sheath, and grooves the back of the internal malleolus, on its way to the inner border of the foot. Its tendon then spreads out and is **inserted** by three bands into (1) the navicular and internal cuneiform bones, (2) the second, third, and fourth metatarsal bones, the middle and external cuneiform and the cuboid bones, and (3) by a recurrent slip into the inner border of the sustentaculum tali of the os calcis (Fig. 262).

In the leg the tibialis posticus is concealed, as it lies on the interosseous membrane between the tibia and fibula, by the superficial muscles and the posterior tibial vessels and nerve. It lies between the flexor longus hallucis and flexor longus digitorum, and is crossed by the tendon of the latter muscle just above the ankle. In the foot its tendon is covered by the long flexor tendons and by the short flexor muscles of the great toe. The tendon is in contact with the inferior calcaneo-navicular ligament in the interval between the sustentaculum tali and the navicular bone.

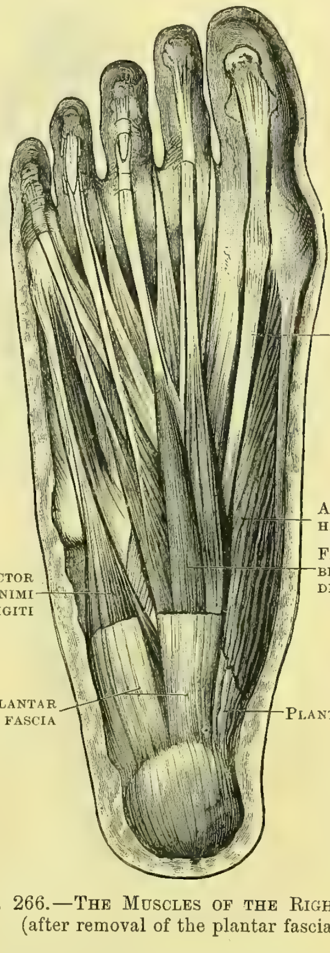


FIG. 266.—THE MUSCLES OF THE RIGHT FOOT (after removal of the plantar fascia).

The **peroneo-calcaneus** muscle, when present, **arises** from the fibula, and is **inserted** into the os calcis.

THE MUSCLES IN THE SOLE OF THE FOOT.

The muscles in the sole of the foot are divisible into four layers placed beneath the plantar fascia.

First layer: Abductor hallucis, flexor brevis digitorum, abductor minimi digiti.

Second layer: Lumbricales and accessorius, together with the tendons of the flexor longus hallucis and flexor longus digitorum.

Third layer: Flexor brevis hallucis, adductors of the great toe, and flexor brevis minimi digiti.

Fourth layer: Interossei (plantar and dorsal).

The **abductor hallucis** has a double **origin** from (1) the greater tubercle on the tuberosity of the os calcis, and (2) the internal annular ligament and plantar fascia. Lying superficially along the inner border of the sole, its tendon is **inserted**, along with part of the flexor brevis hallucis, into the inner side of the first phalanx of the great toe. The muscle lies beneath the plantar fascia, internal to the flexor brevis digitorum, and conceals the plantar vessels and nerves, and near its origin the long flexor tendons.

The **flexor brevis digitorum** has likewise a double **origin**: (1) from the fore-part of the greater tubercle of the tuberosity of the os calcis, and (2) from

the thick central part of the plantar fascia which covers it and the intermuscular septa on either side. Passing forwards, it gives rise to four slender tendons, which are **inserted** into the second phalanges of the four outer toes, after having been perforated, just as in the case of the tendons of the flexor sublimis digitorum of the hand, by the long flexor tendons. Placed in the centre of the sole beneath the plantar fascia, and between the abductor hallucis and abductor minimi digiti muscles, it conceals the second layer of muscles and the external plantar vessels and nerve.

The **abductor minimi digiti** (m. abductor digiti quinti) has also a double **origin**: (1) from both tubercles on the tuberosity of the os calcis, and (2) from the plantar fascia and calcaneo-metatarsal ligament. It lies along the fifth metatarsal bone, and is **inserted** into the outer side of the first phalanx of the little toe. It partially conceals the flexor brevis minimi digiti, and lies on the outer side of the flexor brevis digitorum.

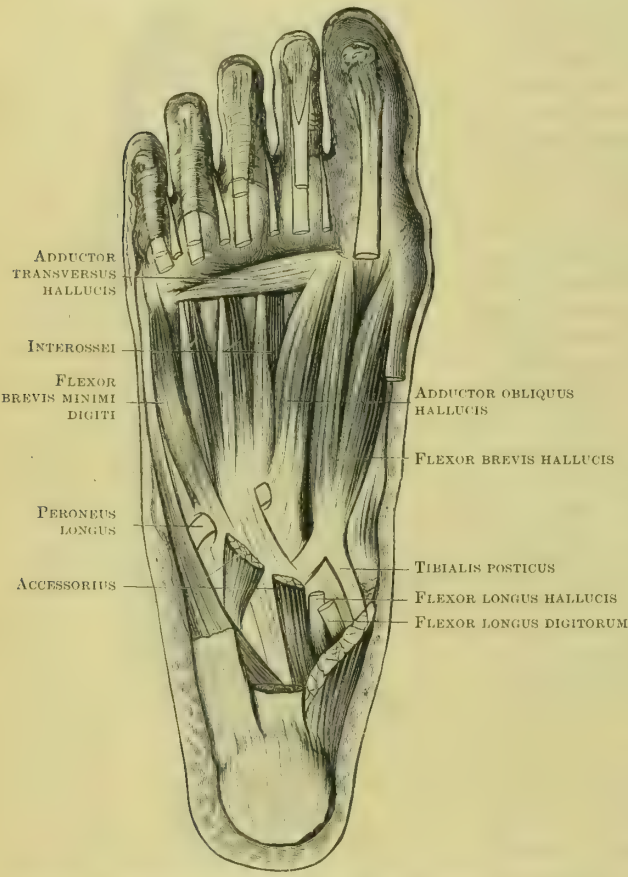


Fig. 267.—The Muscles of the Right Foot (after removal of the second layer).

The tendons of the long flexors of the toes, the **lumbricales** and **accessorius muscles**, constituting the **second layer of muscles**, have already been described. Lying beneath the abductor hallucis and the flexor brevis digitorum, and separated from them by the plantar vessels and nerves, they occupy the hollow of the tarsus and the space between the first and fifth metatarsal bones; their deep surfaces are in contact with the adductors of the great toe and the interossei muscles.

The **flexor brevis hallucis arises** (1) from the inner surface of the cuboid bone, and (2) from the tendon of the tibialis posticus. Directed forwards over the first metatarsal bone, the muscle separates into two parts, between which is the tendon of the flexor longus hallucis. Each portion gives rise to a tendon which is **inserted** into the corresponding side of the base of the first phalanx of the great toe; in each tendon, under the metatarso-phalangeal articulation, a sesamoid bone is developed. The inner tendon is united with the insertion of the abductor, the outer tendon with the insertions of the adductor muscles of the great toe.

The **adductor obliquus hallucis arises** (1) from the sheath of the peroneus longus, and (2) from the heads of the third and fourth metatarsal bones. Occupying the hollow of the foot, deeper than the long flexor tendons and lumbricales, and separated from the interossei by the plantar arch, it is placed on the outer side of the flexor brevis hallucis, and is directed obliquely inwards and forwards, to be **inserted** on the outer side of the base of the first phalanx of the great toe between and along with the flexor brevis and adductor transversus hallucis. The muscle forms one side of a triangular space in the sole through which the external plantar vessels and nerve pass.

The **adductor transversus hallucis** **arises** from (1) the capsules of the outer four metatarso-phalangeal articulations and (2) the transverse metatarsal ligament. Directed transversely inwards, under cover of the flexor tendons and lumbricales, the muscle is **inserted**, along with the adductor obliquus (from which it is separated by an angular interval), into the outer side of the base of the first phalanx of the great toe.

The **flexor brevis minimi digiti** (m. flexor brevis digiti quinti) **arises** from (1) the sheath of the peroneus longus, and (2) the base of the fifth metatarsal bone. Partially concealed by the adductor minimi digiti, the muscle passes along the fifth metatarsal bone, to be **inserted**, in common with that muscle, into the outer side of the base of the first phalanx of the little toe.

The **interossei muscles** of the foot resemble those of the hand except in one respect. In the hand the line of action of the muscles is the middle line of the middle finger. In the foot the *second toe* is the digit round which the muscles are grouped, and their attachments and actions differ accordingly.

There are four dorsal and three plantar muscles, which occupy together the four interosseous spaces, and project into the hollow of the foot.

The **four dorsal muscles**, one in each interosseous space, **arise** by two heads each from the shafts of the metatarsal bones. Each gives rise to a tendon, which, after passing above the transverse metatarsal ligament, is **inserted** on the dorsum of the foot into the side of the first phalanx, the metatarso-phalangeal capsule, and the dorsal expansion of the extensor tendon. The *first* and *second muscles* are inserted into the second toe on the tibial and fibular sides respectively. The *third* and *fourth muscles* are inserted into the third and fourth toes on their fibular sides.

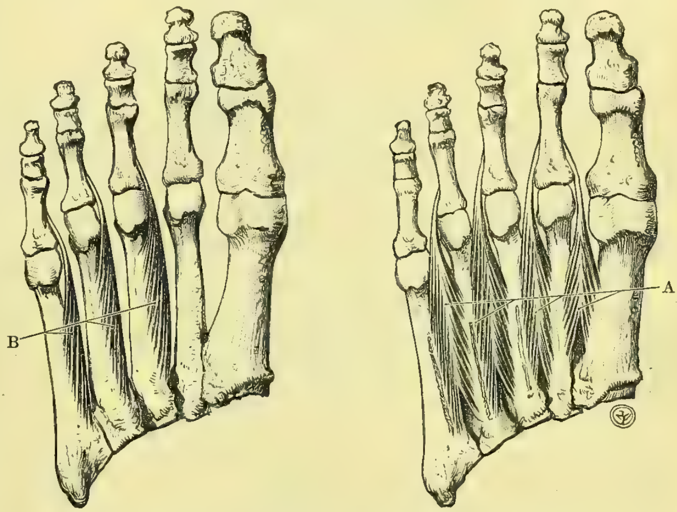


Fig. 268.—Interosseous Muscles of the Foot.
A, Dorsal muscles of the left foot; B, Plantar muscles of the right foot.

The **three plantar muscles** occupy the three outer interosseous spaces. Each **arises** by a single head from the tibial side of the third, fourth, and fifth metatarsal bones respectively. Each ends in a tendon which passes beneath the transverse metatarsal ligament, and is **inserted**, in the same manner as the dorsal muscles, into the third, fourth, and fifth toes on their tibial side.

Nerve-Supply of the Muscles of the Leg and Foot.

Muscles.	Nerves.	Origin.
Tibialis anticus	anterior tibial	L. 4. 5. S. 1.
Extensor proprius hallucis		
Extensor longus digitorum		
Peroneus tertius		
Peroneus longus	musculo-cutaneous	
Peroneus brevis		
Extensor brevis digitorum	anterior tibial	
Plantaris	tibial	L. 4. 5. S. 1.
Popliteus		
Gastrocnemius		S. 1. 2.
Soleus		

Nerve-Supply of the Muscles of the Leg and Foot—*continued.*

Muscles.	Nerves.	Origin.
Soleus		L. 5. S. 1. 2.
Flexor longus digitorum . .	posterior tibial .	L. 5. S. 1.
Tibialis posticus		L. 5. S. 1.
Flexor longus hallucis . . .		L. 5. S. 1. 2.
Abductor hallucis		
Flexor brevis digitorum . .	internal plantar .	L. 4. 5. S. 1.
Flexor brevis hallucis . . .		
First Lumbricalis		
Second, third, and fourth lumbricales		
Flexor accessorius		
Adductores hallucis . . .	external plantar .	S. 1. 2.
Interossei		
Flexor brevis minimi digiti . .		
Abductor minimi digiti . .		

Action of the Muscles of the Leg and Foot.

The muscles of the leg and foot act chiefly in the movements of the ankle-joint (assisted by movements of the inter-tarsal joints); of the metatarso-phalangeal joints (assisted by movements of the tarso-metatarsal and inter-metatarsal joints); and of the inter-phalangeal joints of the several toes.

I. Tibio-Fibular Articulations.—The upper tibio-fibular articulation is only capable of slight gliding movement, occasioned by the action of the biceps and popliteus and the muscles arising from the fibula.

II. Movements at the Ankle-Joint.—The movements at the ankle-joint are movements of flexion and extension of the foot on the leg, along with inversion and eversion (only during extension). These movements are produced at the ankle, aided by movements in the inter-tarsal joints, and are occasioned by the following muscles:—

a. **Flexion.**	**Extension.**	*b.* **Inversion.**	**Eversion.**
Tibialis anticus	Gastrocnemius	Tibialis anticus	Peroneus tertius
Extensor communis digitorum	Plantaris		Peroneus longus
Extensor proprius hallucis	Soleus	Tibialis posticus	Peroneus brevis
Peroneus tertius	Tibialis posticus		
	Peroneus longus		
	Peroneus brevis		
	Flexor longus digitorum		
	Flexor longus hallucis		

III. Movements of the Toes—*A.* **At the Metatarso-Phalangeal Joints** (assisted by movements at the tarso-metatarsal and inter-metatarsal joints).—These movements are flexion and extension, abduction and adduction (in a line corresponding to the axis of the second toe).

a. **Flexion.**	**Extension.**
Flexor longus digitorum	Extensor longus digitorum
Accessorius	
Lumbricales	Extensor brevis digitorum
Flexor longus hallucis	
Flexor brevis hallucis	Extensor proprius hallucis
Flexor brevis digitorum	
Flexor brevis minimi digiti	
Interossei	

b. **Abduction.**	**Adduction.**
(*From and to the middle line of the second toe*).	
Abductor hallucis	Adductores hallucis
Dorsal interossei	Plantar interossei
Abductor minimi digiti	

B. **At the inter-phalangeal joints** the movements are limited to flexion and extension.

Flexion.	Extension.
Flexor brevis digitorum (*acting on the first joint*) Flexor longus digitorum (*acting on both joints*) Flexor longus hallucis (*acting on the hallux*)	Extensor longus digitorum Extensor brevis digitorum Interossei Lumbricales } (*acting on both joints*) Extensor proprius hallucis

Movements of the Lower Limb generally.

The characteristic features of the lower limb are stability and strength, and both its muscles and joints are subservient to the functions of transmission of weight and locomotion. In the standing position the centre of gravity of the trunk falls between the heads of the femora, and is located about the middle of the body of the last lumbar vertebra. It is transmitted through the bones of the lower limb to the arch of the foot, where the astragalus distributes it backwards through the os calcis to the heel, and forwards through the tarsus and metatarsus to the balls of the toes.

Locomotion.—The three chief means of progression are walking, running, and leaping. In **walking**, the body and its centre of gravity are inclined forwards, the trunk oscillates from side to side as it is supported alternately by each foot, the arms swing alternately with the corresponding leg, and one foot is always on the ground. The act of progression is performed by the leg, aided in two ways by gravity. The movements of the leg are as follows :—At the beginning of a step, one leg, so to speak, "shoves off;" the heel is raised and the limb is extended. By the action of the muscles flexing the hip and knee-joint, and extending the ankle-joint and toes, this limb is raised from the ground sufficiently to clear it, and passes forwards by the action of gravity, aided by the force given to the movement by the extensor muscles. After passing the line of the centre of gravity the flexion of the joints ceases, the muscles relax, and the limb gradually returns to the ground. The other limb then passes through the same cycle, the weight of the body now resting on the limb which is in contact with the ground. As the foot reaches the ground it, as it were, rolls over it; the heel touches it first, then the sole, and lastly, as the foot leaves the ground again, only the toes. In **running**, the previous events are all exaggerated. The time of the event is diminished, while the force and distance are increased. Both feet are off the ground at one time ; the action of flexors and extensors alternately is much more powerful, so that on the one hand the knees are drawn upwards to a greater extent in the forward movement, and not the whole foot but only the toes reach the ground in the extension of the limb. The attempt is made to bring the foot to the ground in front of the line of the centre of gravity. At the same time the trunk is sloped forwards much more than in walking. In **leaping**, the actions of the limbs are still more exaggerated. The movements of flexion of the limb are still more marked, and the foot reaches the ground still further in front of the line of the centre of gravity.

AXIAL MUSCLES.

THE FASCIÆ AND MUSCLES OF THE BACK.

THE FASCIÆ OF THE BACK.

The general fascial investments of the back have been described (p. 307) along with the superficial muscles associated with the shoulder. The latissimus dorsi muscle has been described as arising in large part from the **vertebral aponeurosis.** This is a strong fibrous lamina which conceals the erector spinæ muscle. In the loin it extends from the spines of the lumbar vertebræ outwards to the interval between the last rib and the iliac crest, where it is concerned in forming the **lumbar fascia.** Below the loin the vertebral aponeurosis is attached to the iliac crest, and more internally blends with the subjacent tendinous origin of the erector spinæ. The fascia can be followed upwards over the erector spinæ in the region of the thorax, where it is attached externally to the ribs and is continuous with the intercostal aponeuroses. In the lower part of the thorax it is replaced by muscular slips—the serratus posticus inferior; in the upper part of the thorax it passes beneath the serratus posticus superior and blends with the deep cervical fascia.

The **lumbar fascia** is a narrow ligamentous band which connects the last rib to

the iliac crest between the muscles of the back and abdominal wall. It is formed by the union of three fascial strata, called respectively the **vertebral aponeurosis** or posterior layer, just described; the middle and the anterior layers. The **middle layer** is a fascia which stretches outwards from the ends of the transverse processes of the lumbar vertebræ, between the erector spinæ behind and the quadratus lumborum muscle in front. The **anterior layer** is attached to the lumbar vertebræ at the junction of their transverse processes and bodies. It covers the front of the quadratus lumborum muscle, and separates it from the psoas. At the outer borders of the quadratus lumborum and erector spinæ muscles the three layers are blended together to form the lumbar fascia, which in turn gives partial origin to the obliquus internus and transversalis abdominis muscles.

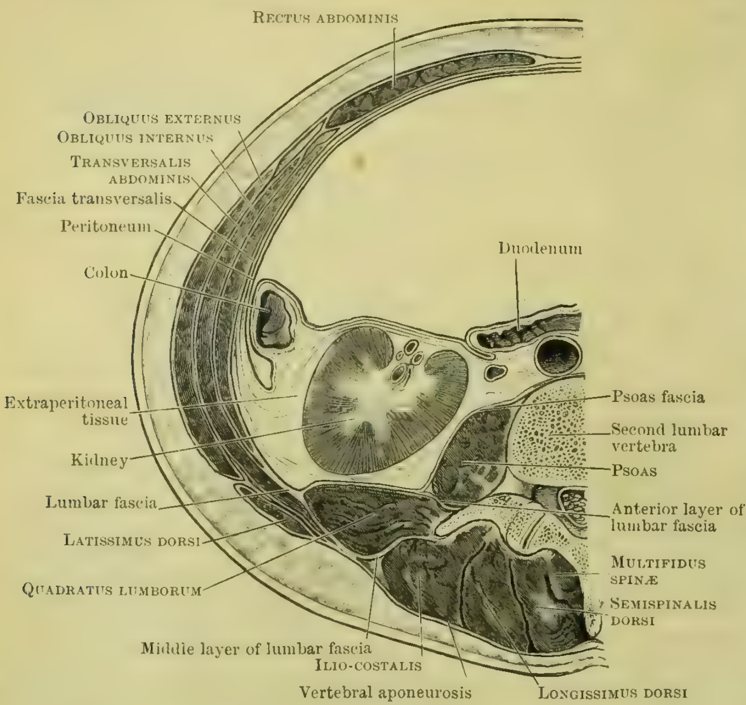


FIG. 269.—TRANSVERSE SECTION THROUGH THE ABDOMEN, OPPOSITE THE SECOND LUMBAR VERTEBRA.

THE MUSCLES OF THE BACK.

The muscles of the back are arranged in four series according to their attachments: (1) vertebro-scapular and vertebro-humeral, (2) vertebro-costal, (3) vertebro-cranial, and (4) vertebral. They are in irregular strata, the most superficial muscles having the most widely separated attachments.

The first series of muscles of the back, connecting the axial skeleton to the upper limb, have already been described. They are arranged in two layers: (1) trapezius and latissimus dorsi, superficially; (2) levator anguli scapulæ, and rhomboidei beneath the trapezius.

The remaining muscles are almost entirely axial, and may be divided into four groups: (1) serrati postici, superior and inferior, and splenius capitis and colli; (2) erector spinæ and complexus; (3) transverso-spinales (semispinalis and multifidus spinæ); and (4) the small deep muscles (rotatores, interspinales, intertransversales, and suboccipital muscles).

FIRST GROUP.

The **serratus posticus superior** has a membranous **origin** from the ligamentum nuchæ and the spines of the last cervical and upper three or four thoracic vertebræ. It is directed obliquely downwards and outwards, to be **inserted** by separate slips into the second, third, fourth, and fifth ribs. The muscle is concealed by the vertebro-scapular muscles, and crosses obliquely the splenius, erector spinæ, and complexus. It lies superficial to the vertebral aponeurosis.

The **serratus posticus inferior** has a membranous **origin** through the medium

of the vertebral aponeurosis from the last two thoracic and first two lumbar spinous processes. It forms four muscular bands which pass almost horizontally outwards to an **insertion** into the last four ribs. The muscular slips overlap one another from below upwards. The muscle is on the same plane as the vertebral aponeurosis, and is concealed by the latissimus dorsi.

The **splenius muscle** occupies the back of the neck and upper part of the thoracic region. It **arises** as a flattened band from the ligamentum nuchæ (from the level of the fourth cervical vertebra downwards) and from the spinous processes of the last cervical and higher (four to six) thoracic vertebræ. Its fibres extend upwards and outwards into the neck, separating in their course into an upper and a lower part. The upper part forms the **splenius capitis**, which is **inserted** into the mastoid process and the outer part of the superior curved line of the occipital bone. The lower part forms the **splenius colli** or **cervicis**, which is **inserted** into the posterior tubercles of the transverse processes of the upper three or four cervical vertebræ behind the origin of the levator anguli scapulæ. The muscle is partially concealed by the trapezius and sternomastoid, and appears between them in the floor of the posterior triangle of the neck. It is covered by the rhomboid muscles, levator anguli scapulæ and serratus posticus superior. It conceals the transversalis cervicis, trachelo-mastoid, and complexus muscles.

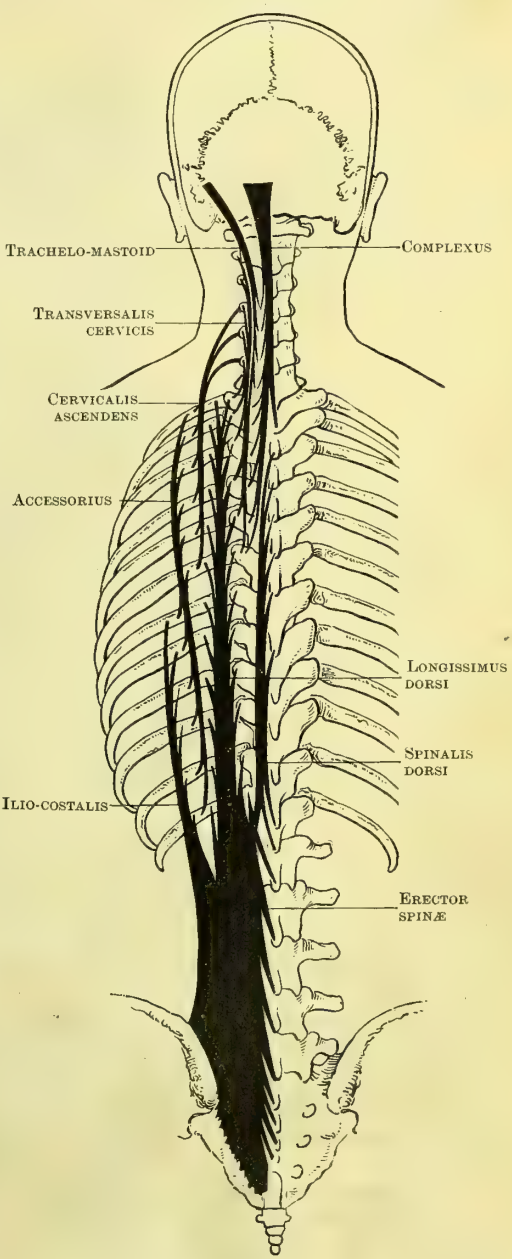


Fig. 270.—Schematic Representation of the Parts of the Erector Spinæ Muscle.

Second Group.

The **erector spinæ** (m. sacro-spinalis) possesses vertebral, vertebro-cranial, and vertebro-costal attachments. It consists of an elongated mass composed of separated slips extending from the sacrum to the skull. Simple at its origin, it becomes more and more complex as it is traced upwards towards the head. It **arises** (1) by fleshy fibres from the iliac crest; (2) from the posterior sacro-iliac ligament; and (3) by tendinous fibres continuous with the former from the iliac crest, the back of the sacrum, and the spines of the upper sacral and all the lumbar vertebræ. Its fibres extend upwards through the loin, enclosed between the posterior and middle layers of the lumbar fascia, and separate into two columns, an outer portion derived from the external fleshy origin, the **ilio-costalis**, and an inner portion comprising the remaining larger part of the muscle, the **longissimus dorsi.**

The **ilio-costalis** (m. ilio-costalis lumborum) is **inserted** by six slender slips into the lower six ribs.

Internal to the insertion of each is the origin of a slip of the **accessorius muscle** (m. ilio-costalis dorsi), which, **arising** from the lower six ribs internal to the ilio-costalis, is **inserted** in line with it by similar slips into the upper six ribs.

The **cervicalis ascendens** (m. ilio-costalis cervicis) **arises** in the same way by six slips from the upper six ribs, internal to the insertions of the accessorius. It forms a narrow band, which, extending into the neck, is **inserted** into the posterior tubercles of the transverse processes of the fourth, fifth, and sixth cervical vertebræ, behind the scalenus posticus. The ilio-costalis, accessorius, and cervicalis ascendens form together a continuous muscular column, and constitute the outermost group of the component elements of the erector spinæ.

The **longissimus dorsi** is the largest element in the erector spinæ. Mostly tendinous on the surface at its origin, it becomes fleshy in the upper part of the loin, and is **inserted,** by an inner and an outer series of slips, externally into nearly all the ribs, and internally into the transverse processes of the thoracic and the accessory processes of the upper lumbar vertebræ. It is prolonged upwards into the

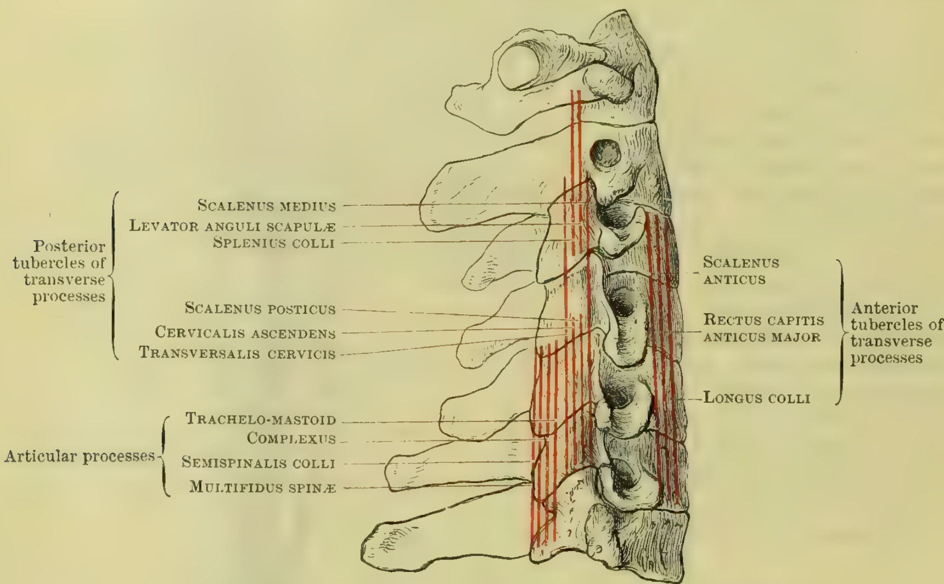


Fig. 271.—Scheme of Muscular Attachments to Cervical Vertebræ.

neck by its association with the common origin of two muscles, the transversalis cervicis and the trachelo-mastoid.

The **transversalis cervicis** (m. longissimus cervicis) has an **origin** from the transverse processes of the upper six thoracic vertebræ, internal to the insertions of the longissimus dorsi. Extending upwards into the neck, it is **inserted**, underneath the cervicalis ascendens and splenius colli muscles, into the posterior tubercles of the transverse processes of the second, third, fourth, fifth, and sixth cervical vertebræ.

The **trachelo-mastoid** (m. longissimus capitis) **arises,** partly by an origin common to it and the previous muscle, from the transverse processes of the upper six thoracic vertebræ, and partly by an additional origin from the articular processes of the lower four cervical vertebræ. Separating from the transversalis cervicis, the muscle ascends through the neck as a narrow band which intervenes between the splenius capitis and complexus, and is **inserted** into the mastoid process beneath the former muscle.

The longissimus dorsi, with its cervical prolongations, forms the middle column of muscles in the erector spinæ.

The **spinalis dorsi arises** by tendinous fibres from the lower two thoracic and upper two lumbar spinous processes, and also directly from the tendon of the longissimus dorsi. It is a narrow muscle which, lying close to the thoracic spinous processes internal to the longissimus dorsi and complexus, is **inserted** into the

upper (four to eight) thoracic spines. This muscle is not prolonged into the neck. It conceals the next group of muscles, and forms the innermost column of the erector spinæ muscle.

The erector spinæ muscle is bound down by the vertebral aponeurosis, and is concealed by the more superficial muscles (sterno-mastoid, trapezius, levator

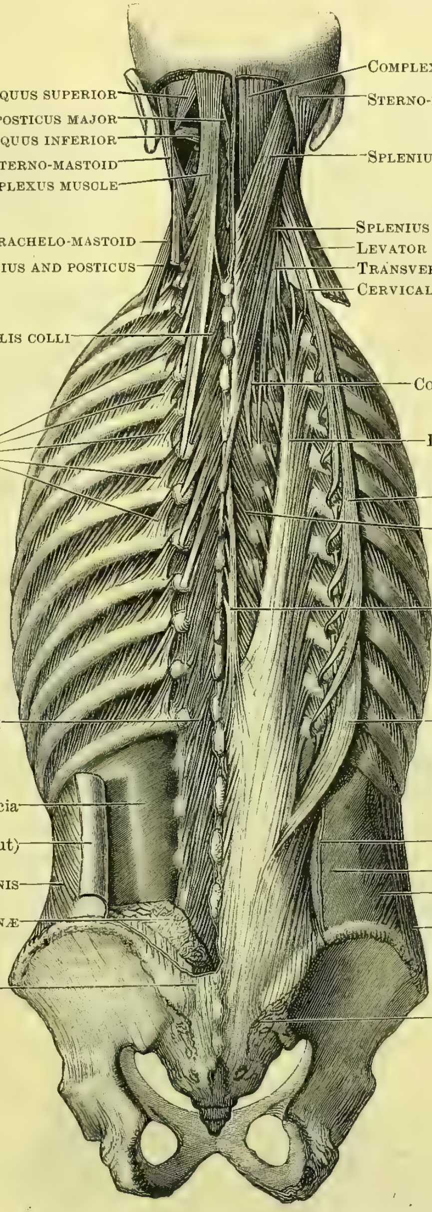


Fig. 272.—Deeper Muscles of the Back.

scapulæ, rhomboids, splenius, serrati postici). It covers the ribs posteriorly, and partially conceals the semispinales and complexus muscles.

The **complexus muscle** (m. semispinalis capitis) closely resembles in position and attachments the trachelo-mastoid. It takes **origin** from the transverse processes of the upper six thoracic and the articular processes of the lower four cervical vertebræ, internal to the transversalis cervicis and trachelo-mastoid. It has an additional origin also from the spinous process of the last cervical vertebra. It forms a broad muscular sheet which extends upwards in the neck, to be **inserted** between the superior and inferior curved lines of the occipital bone. The inner

portion of the muscle is separate, and forms the **biventer cervicis**, consisting of two fleshy bellies with an intervening tendon placed vertically in contact with the ligamentum nuchæ. The insertion of the muscle is crossed by the occipital artery. The complexus is covered mainly by the splenius and trachelo-mastoid muscles. It conceals the semispinalis colli and the muscles of the suboccipital triangle, along with the accompanying vessels and nerves.

Third Group.

These muscles are only incompletely separate from one another. The semispinalis dorsi and colli form a superficial stratum, the multifidus spinæ being more deeply placed. The more superficial muscle has the longer fibres; the fibres of the multifidus spinæ pass over fewer vertebræ. Both muscles extend obliquely upwards from transverse to spinous processes.

The **semispinalis muscle** extends from the loin to the axis. Its fibres are artificially separated into an inferior part, the **semispinalis dorsi**, and a superior part, the **semispinalis colli.**

The **semispinalis dorsi arises** from the transverse processes of the lower six thoracic vertebræ. It is **inserted** into the spinous processes of the last two cervical and first four thoracic vertebræ.

The **semispinalis colli** or **cervicis arises** from the transverse processes of the upper six thoracic vertebræ and the articular processes of the lower four cervical vertebræ. It is **inserted** into the spines of the cervical vertebræ from the second to

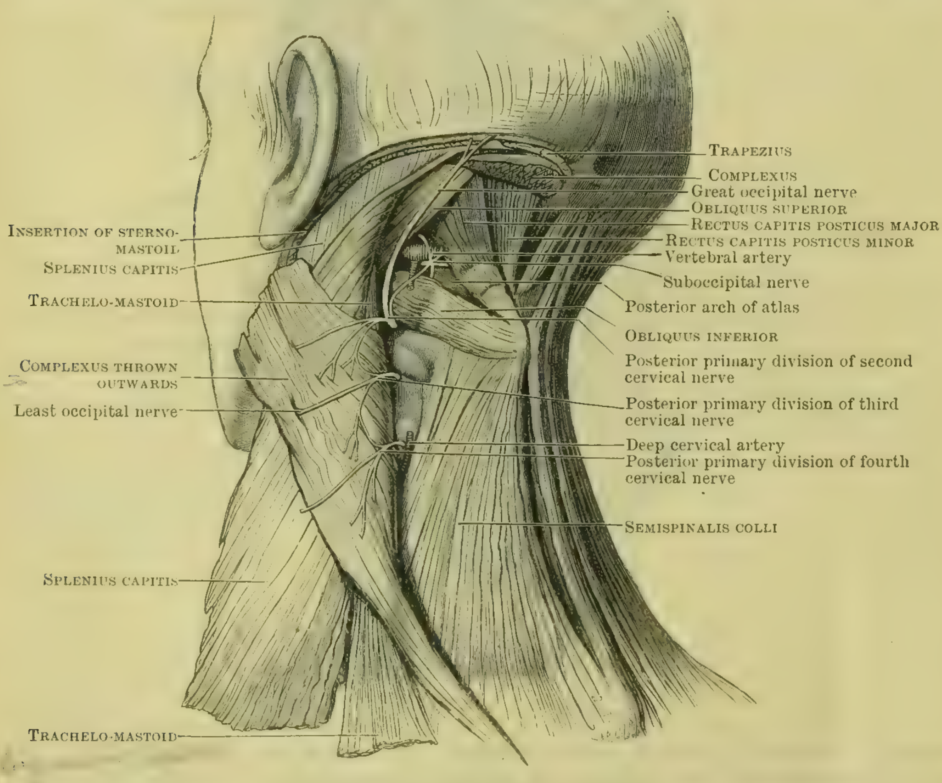


Fig. 273.—The Suboccipital Triangle.

the fifth. The semispinalis muscle occupies the vertebral furrow, and is concealed by the erector spinæ and complexus; it covers the multifidus spinæ muscle. It is on the same plane as the muscles of the suboccipital triangle.

The **multifidus spinæ** differs from the previous muscle in extending from the sacrum to the axis, and in the shortness of its fasciculi, which pass over fewer vertebræ to reach their insertion. It **arises** from the sacrum, from the sacro-iliac

ligament, from the mammillary processes of the lumbar vertebræ, from the transverse processes of the thoracic vertebræ, and from the articular processes of the lower four cervical vertebræ. It is **inserted** into the spines of the vertebræ up to and including the axis. Lying in contact with the vertebral laminæ, the muscle is covered by the semispinalis.

Fourth Group.

The muscles bounding the **suboccipital triangle** are four in number—obliquus inferior, obliquus superior, rectus capitis posticus major, and rectus capitis posticus minor.

The **obliquus inferior arises** from the spine of the axis, and is **inserted** into the transverse process of the atlas.

The **obliquus superior arises** from the transverse process of the atlas, and is **inserted** into the occipital bone external to the complexus and above the inferior curved line.

The **rectus capitis posticus major arises** from the spine of the axis, and is **inserted** into the occipital bone beneath the obliquus superior and complexus, and below the inferior curved line.

The **rectus capitis posticus minor arises** beneath the previous muscle from the spine of the atlas, and is **inserted** into the occipital bone below the inferior curved line and beneath the rectus capitis posticus major.

These muscles are concealed by the complexus and splenius capitis; they enclose a triangular space (the suboccipital triangle) in which the vertebral artery, suboccipital nerve, and the posterior arch of the atlas are contained. The obliquus inferior is separated from the semispinalis muscle by the great occipital (second cervical) nerve.

The **rotatores dorsi** are eleven pairs of small muscles occupying the vertebral groove in the thoracic region, beneath the transverso-spinales, of which they form the deepest fibres. Each consists of a small slip **arising** from the transverse process, and **inserted** into the lamina of the vertebra directly above.

The **inter-spinales** are bands of muscular fibres connecting together the spinous processes of the vertebræ.

The **inter-transversales** are slender slips extending between the transverse processes. They are double in the neck, the anterior divisions of the spinal nerves passing between them.

The **rectus capitis lateralis,** extending from the transverse process of the atlas to the jugular process of the occipital bone, is homologous with the posterior of the two inter-transverse muscles. In the loin the inter-transversales muscles are usually double, but they are often absent, or are replaced by membrane.

Nerve Supply.

With the exception of the vertebro-scapular and vertebro-humeral muscles (trapezius, latissimus dorsi, levator anguli scapulæ, rhomboidei), the muscles of the back are all supplied by the *posterior primary divisions* of the spinal nerves. In the upper part of the trunk the muscles are supplied mainly by the external branches; in the lower part chiefly by the internal branches of the nerves. In the cervical and sacral regions a limited plexiform arrangement of the nerves occurs (*posterior cervical* and *posterior sacral plexuses*).

Actions.

The action of these muscles is extremely complex. Not only do they act on the spinal column, ribs, head, and pelvis, in conjunction with other muscles, but some of them act also in relation to the movements of the limbs as well. In this section will be given an analysis of their movements in relation to the spinal column, head, and pelvis. The movements of the limbs and of the ribs (respiration) are dealt with in other sections. The chief muscles are engaged in preserving the erect position, and in the movements of the trunk they are assisted in large measure by muscles whose chief movements are referred to elsewhere (p. 350).

1. Movements of the Spinal Column.—The movements of the vertebral column are flexion, extension, and lateral movement or rotation.

a. **Flexion**	and **Extension.**
Longus colli	Serrati postici
Rectus capitis anticus major	Splenius capitis
Scaleni antici (together)	Splenius colli
Psoas magnus and parvus	Erector spinæ
Levator ani	Semispinalis dorsi
Ischio-coccygeus	Semispinalis colli
	Complexus
Sphincter ani externus	Multifidus spinæ
Rectus abdominis	Interspinales
Pyramidalis abdominis	
Obliquus externus abdominis	Intercostal muscles
Obliquus internus ,,	Diaphragm
Transversalis ,,	Triangularis sterni

b. **Lateral Movement (Rotation).**	
Levator anguli scapulæ	Rectus capitis anticus major
Serrati postici	Scaleni, anticus, medius, posticus.
Splenius colli	Psoas magnus and parvus
Erector spinæ	Quadratus lumborum
Complexus	Obliquus externus abdominis
Semispinalis	Obliquus internus ,,
Multifidus spinæ	Transversalis ,,
Rotatores dorsi	Rectus ,,
Inter-transversales	Pyramidalis ,,
Longus colli	

2. Movements of the Head.—The movements of the head are flexion and extension, at the occipito-atlantoid articulation; lateral movement and rotation at the atlanto-axial joint.

a. **Flexion**	and **Extension.**
Digastric	Sterno-mastoid
Stylo-hyoid	Splenius capitis
Stylo-pharyngeus	Trachelo-mastoid
Mylohyoid	Complexus
Hyoglossus	Obliquus inferior
Sterno-hyoid	Recti capitis postici (major and minor)
Sterno-thyroid	
Omo-hyoid	
Recti capitis antici (major and minor) (*the muscles of both sides acting together*)	

b. **Lateral Movement.**	*c.* **Rotation.**
Sterno-mastoid	Sterno-mastoid
Splenius capitis	Splenius capitis
Trachelo-mastoid	Trachelo-mastoid
Complexus	Complexus
Obliquus superior	Obliquus inferior
Rectus capitis lateralis	,, superior
	Recti capitis postici (major and minor)

3. Movements of the Pelvis.—The movements of the pelvis (as in locomotion) are partly caused by certain of the muscles of the back. Those muscles, which are attached to the spinal column or the ribs on the one hand, and to the innominate bone on the other, produce the movements (flexion, extension, and lateral movement) of the whole pelvis. In addition, the muscles passing between the innominate bone and femur, in certain positions of the lower limb, assist in these movements.

a. **Extension**	and **Flexion.**
Latissimus dorsi Erector spinæ Multifidus spinæ (acting on both sides)	Psoas magnus and parvus Rectus abdominis Pyramidalis abdominis Obliquus externus abdominis Obliquus internus ,, Transversalis abdominis (acting on both sides) Pyriformis Glutei Obturator (externus and internus) Sartorius Tensor fasciæ femoris Iliacus Rectus femoris Adductors (in erect position)
b. **Lateral Movement.**	
Flexors and extensors of side only	Quadratus lumborum

THE FASCIÆ AND MUSCLES OF THE HEAD AND NECK.

FASCIÆ.

The **superficial fascia** of the head and neck possesses certain features of special interest. Over the scalp it is closely adherent to the skin and subjacent epicranial aponeurosis, and contains the superficial vessels and nerves. Beneath the skin of the eyelids it is loose and thin and contains no fat. Over the face and at the side of the neck it is separated from the deep fascia by the facial muscles and the platysma myoides. In the hollow between the buccinator and the masseter it is continuous with a pad of fat (*suctorial pad*) occupying the interval between these muscles.

The **deep fascia** of the head and neck presents many remarkable characters. *Over the scalp* it is represented by the **epicranial aponeurosis,** the tendon of the occipito-frontalis muscle. This is a tough membrane, tightly stretched over the calvarium, from which it is separated by loose areolar tissue. It is attached posteriorly, partly through the agency of the occipitalis muscle, to the superior curved line of the occipital bone; anteriorly it joins the frontalis muscle and the orbicularis palpebrarum, and has no bony attachment; laterally it is attached to the temporal ridge and the mastoid process. Below the temporal ridge it is continuous with the **temporal fascia,** a stout layer of fascia attached to the temporal ridge and zygomatic arch, which covers and gives origin to the temporal muscle. This fascia separates into two layers above the zygoma, to enclose a quantity of fat along with branches of the temporal and orbital arteries. On the face the fascia is practically non-existent anteriorly in relation to the facial muscles. Posteriorly it forms the thin **masseteric fascia,** and is much thicker in relation to the parotid gland, for which it forms a capsule.

In the neck the deep fascia invests the muscles, and forms aponeurotic coverings for the pharynx, trachea, œsophagus, glands, and large vessels. It encloses the sterno-mastoid muscle, and can be traced backwards over the posterior triangle to the trapezius and deeper muscles, which it surrounds; it can be traced forwards over the anterior triangle to the middle line of the neck, over which it forms a continuous membrane. *Above the sternum* the fascia, after enclosing the sterno-mastoid, is attached in the form of two layers to the front and back of the episternal notch. The layer enclosing the infrahyoid muscles passes across the middle line of the neck in front of the trachea, and is attached above to the hyoid bone, below to the sternum, clavicle, and first rib. A third layer of fascia passes inwards in front of the trachea, enclosing the thyroid body. Beneath the sterno-

mastoid the fascia helps to form the **carotid sheath**, which is completed by septal processes stretching inwards across the neck in relation to the infrahyoid muscles, trachea, œsophagus and pharynx, and the prevertebral muscles. The trachea, œsophagus, and pharynx, are likewise encapsuled in cervical fascia, a septal layer passing across the middle line of the neck between the trachea and œsophagus. Lastly, a strong **prevertebral fascia** passes across the neck in front of the prevertebral muscles, and behind the œsophagus and pharynx.

The cervical fascia is attached above to the **bones of the skull**: superficially to the superior curved line of the occipital bone, the mastoid process, the zygoma (over the parotid gland) and the lower border of the mandible; more deeply to the styloid and vaginal processes of the temporal bone, the great wing of the sphenoid and the basilar process. This deeper attachment is behind the parotid gland and pharynx, and is associated with the formation of three ligaments: **stylo-mandibular ligament, internal lateral ligament** of the lower jaw, and **pterygo-spinous ligament.** The fascia is attached below, through its muscular connexions, to the sternum, first rib, clavicle, and scapula. By means of its connexion with the trachea and the common carotid artery it is carried down behind the first rib into the superior mediastinum, and becomes ultimately continuous with the pericardium. By means of its connexion with the subclavian artery it is carried down to the axilla, as the subclavian sheath, which becomes connected with the costo-coracoid membrane.

FIG. 274.—TRANSVERSE SECTION IN THE CERVICAL REGION (between the fourth and fifth cervical vertebræ.)

1. CRICOTHYROID MUSCLE.
2. INFERIOR CONSTRICTOR MUSCLE.
3. Pharynx.
4. Cricoid cartilage.
5. Vocal cord.
6. THYRO-ARYTENOID MUSCLE.
7. Thyroid cartilage.
8. Glottis.
9. Layers of deep cervical fascia.
10. STERNOHYOID MUSCLE.
11. OMOHYOID MUSCLE.
12. STERNOTHYROID MUSCLE.
13. Cervical fascia.
14. Thyroid body.
15. Common carotid artery.
16. Descendens hypoglossi nerve.
17. STERNOMASTOID MUSCLE.
18. Internal jugular vein.
19. Pneumogastric nerve.
20. Sympathetic nerve.
21. Carotid sheath.
22. Phrenic nerve.
23. LONGUS COLLI MUSCLE.
24. Rectus capitis anticus major.
25. Scalenus anticus.
26. Vertebral vein.
27. Scalenus medius.
28. Posterior triangle.
29. Scalenus posticus.
30. Levator anguli scapulæ.
31. Spinal accessory nerve.
32. Splenius colli.
33. ~~Transversalis~~ cervicis.
34. Trachelo-mastoid.
35. Spinal nerve.
36. Vertebral artery.
37. Profunda cervicis vein.
38. Profunda cervicis artery.
39. Multifidus spinæ.
40. Semispinalis colli.
41. Complexus.
42. Splenius capitis.
43. Trapezius.
44. Ligamentum nuchæ.
45. Spine of fourth cervical vertebra.
46. Lamina of fifth cervical vertebra.
47. Dura mater.
48. Spinal cord.
49. Transverse process.
50. Body of fifth cervical vertebra.

THE MUSCLES OF THE HEAD.

The muscles of the head are divisible into three separate groups with very different relations and uses—viz., superficial muscles, muscles of the orbit, and muscles of mastication.

The **superficial muscles** comprise a large group, including the muscles of the scalp and face and the platysma myoides in the neck.

The **platysma myoides** is a thin quadrilateral sheet extending from chest to

face over the side of the neck, between the superficial and deep fasciæ. It **arises** from the deep fascia of the pectoral region and the clavicle. It is directed upwards and forwards, and is partly **inserted** (by its middle fibres) into the lower border of the mandible, becoming connected with the depressor labii inferioris and depressor anguli oris muscles. The more anterior fibres pass across the middle line of the neck and decussate below the chin with those of the opposite side. The posterior fibres sweep over the angle of the jaw and become continuous with the

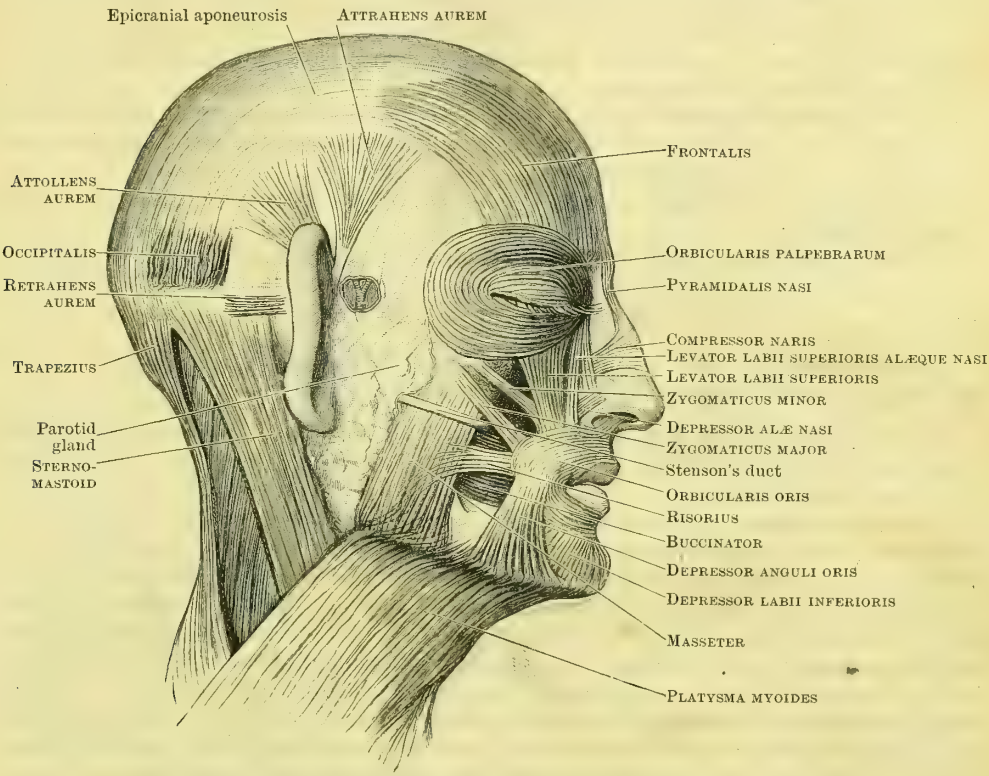


FIG. 275.—THE MUSCLES OF THE FACE AND SCALP (muscles of expression).

risorius muscle. The platysma myoides is the rudiment of the cervical portion of the **panniculus carnosus** of lower animals, in which it has a much more intimate connexion with the muscles of the face than is usually the case in man.

THE MUSCLES OF THE SCALP.

The muscles of the scalp comprise the muscles of the external ear and the occipito-frontalis muscle.

The **occipito-frontalis** is a muscle with two bellies and an intervening tendon (the epicranial aponeurosis) which stretches uninterruptedly across the middle line of the cranium. The **posterior belly** (occipitalis) **arises** from the outer two-thirds of the superior curved line of the occipital bone as a broad flat band. The **anterior belly** (frontalis) has no bony attachments; **arising** from the epicranial aponeurosis about the level of the coronal suture, it passes downwards to the supra-orbital arch, where it is inserted into the orbicularis palpebrarum and corrugator supercilii muscles. It extends the full width of the forehead, and blends internally with the muscle of the opposite side.

The **epicranial aponeurosis** extending between the two fleshy bellies, is a continuous membrane which glides over the calvarium, and has attachments laterally to the temporal ridge, and behind between the posterior bellies to the superior curved line of the occipital bone. It has no osseous attachment anteriorly. The occipito-frontalis is usually rudimentary. By the contraction of the fibres of the

frontalis muscle the skin of the forehead is thrown into horizontal parallel folds.

The **extrinsic muscles of the ear** are three in number: retrahens, attollens, and attrahens aurem.

The **retrahens aurem** (m. auricularis posterior) is a narrow fleshy slip which **arises** from the surface of the mastoid process and is **inserted** into the deep surface of the pinna. It bridges across the groove between the mastoid process and the pinna, and conceals the posterior auricular vessels and nerve.

The **attollens aurem** (m. auricularis superior) is a small fan-shaped muscle which **arises** from the temporal fascia, and descends vertically to be **inserted** into the top of the root of the pinna.

The **attrahens aurem** (m. auricularis anterior) is a similar small muscle, placed in front of the attollens, and stretching obliquely between the temporal fascia and the top of the root of the pinna.

These two muscles conceal branches of the temporal vessels as they lie on the temporal fascia.

The ear muscles are rudimentary and usually functionless.

The Muscles of the Face.

The muscles of the face are divided into three groups, associated with the several apertures of the eye, nose, and mouth.

1. The **muscles of the eyelids** include four muscles: the levator palpebræ superioris (described with the orbital muscles), orbicularis palpebrarum, tensor tarsi, and corrugator supercilii.

The **orbicularis palpebrarum** (m. orbicularis oculi) is a transversely oval sphincter muscle surrounding and occupying the eyelids. It is divisible into an *external portion* (pars orbitalis) composed of coarse fibres, spreading on to the forehead, temple, and cheek, and an *internal portion* (pars palpebralis), composed of finer fibres, which occupies the eyelids beneath the skin. At the inner canthus of the eye the muscle (by its palpebral fibres) gains an **attachment** to the tarsal ligament and the borders of the naso-lachrymal groove. The fibres which extend along the margins of the lids constitute a separate **ciliary bundle**. The fibres of the orbicularis palpebrarum enclose the lachrymal sac and the canaliculi. The posterior fibres, extending between the posterior edge of the naso-lachrymal groove and the tarsal ligaments behind the lachrymal sac, constitute the **tensor tarsi muscle**.

Externally the orbicularis palpebrarum has no bony attachment; so that when it contracts and closes the eyelids, both lids at the same time tend to be drawn inwards towards the inner canthus of the eye.

The **corrugator supercilii arises** from the nasal eminence, and passing horizontally outwards, blends with the upper fibres of the preceding muscle on its under surface. The contraction of this muscle throws the forehead into vertical folds.

2. The **muscles of the nose** comprise five small muscles proper to the nose, and one common to the nose and upper lip: the pyramidalis nasi, compressor naris, dilatores naris (anterior and posterior), depressor alæ nasi, and levator labii superioris alæque nasi. They are all small and feeble.

The **pyramidalis nasi arises** from the occipito-frontalis muscle and the skin over the glabella; it is **inserted** into a membrane stretching over the nose, which also gives attachment to the compressor naris.

The **compressor naris** (m. nasalis) **arises** by a narrow origin from the superior maxilla, under cover of the levator labii superioris alæque nasi. It passes forwards over the bridge of the nose, and ends in a membranous **insertion** common to it and the previous muscle.

The **dilatores naris** are feeble muscular slips placed on the outer side of the margin of the nostril, one anteriorly, the other posteriorly.

The **depressor alæ nasi** is a small muscle **arising** from the upper part of the incisor fossa of the maxilla; it divides into two parts as it passes upwards and inwards, and is **inserted** into the ala and the septum of the nose (depressor septi).

The **levator labii inferioris alæque nasi** is a narrow band **arising** from the root of the nasal process of the maxilla. It descends alongside the nose, and is **inserted** partly into the ala of the nose and partly into the orbicularis oris muscle.

3. The **muscles of the mouth** comprise eleven muscles, of which one, the orbicularis, is a single muscle, the others being bilaterally placed: levator labii superioris alæque nasi, levator labii superioris, levator anguli oris, zygomatici (major and minor), risorius, depressor anguli oris, depressor labii inferioris, levator menti, and buccinator.

The **orbicularis oris** is the sphincter muscle surrounding the lips. It is continuous with the other muscles converging to the mouth. It lies between the skin and mucous membrane of the mouth, and is limited above by the nose, below by the junction of lower lip and chin. Its mesial fibres are attached above to the septum of the nose (naso-labial band) and to the incisor fossa (superior incisive bundle); below to the lower jaw on each side of the symphysis (inferior incisive bundle). These bundles radiate outwards to join the rest of the muscle, which is joined at its margin by the levators and depressors of the lower lip and angle of the mouth, and by the buccinator muscle. The *lower fibres* of the muscle are continued laterally into buccinator and levator anguli oris; its *upper fibres* are continued into the buccinator and depressor anguli oris.

The **levator labii superioris alæque nasi** has been already described.

The **levator labii superioris arises** from the superior maxilla just above the infraorbital foramen. It passes almost vertically downwards to join the orbicularis oris and the skin of the upper lip between the attachments of the levator labii superioris alæque nasi and the levator anguli oris. It conceals the infraorbital vessels and nerve.

The **levator anguli oris arises** from the canine fossa of the upper jaw below the infraorbital foramen and under cover of the foregoing muscle. It is directed outwards and downwards, to be **inserted** into the orbicularis oris and the skin at the angle of the mouth.

The **zygomatici (major and minor)** are more superficial than the preceding muscle.

The **zygomaticus minor** is the anterior muscle. It **arises** from the malar bone, and is often continuous with the most peripheral fibres of the orbicularis palpebrarum. It is directed obliquely downwards and forwards over the levator anguli oris, to be **inserted**, along with the levator labii superioris, into the orbicularis oris. The **zygomaticus major** is a narrow muscular band which **arises** from the malar portion of the zygomatic arch. It passes to the angle of the mouth, to be **inserted** partly into the skin, partly into the orbicularis oris.

The **risorius** is a thin flat muscle which forms partly a continuation of the platysma myoides on the face, partly a separate muscle, with an **origin** from the masseteric fascia. It passes transversely forwards, to be **inserted** at the angle of the mouth into the orbicularis oris and skin.

The **depressor anguli oris arises** from the external oblique line of the lower jaw and from the platysma myoides. It is triangular in form, its fibres converging to the angle of the mouth, where they are **inserted** into the orbicularis oris and the skin. Some of the fibres reach the upper lip through the orbicularis muscle.

The **depressor labii inferioris arises** from the outer surface of the lower jaw beneath and internal to the depressor anguli oris. It is quadrilateral in form, and is directed upwards, to be **inserted** into the orbicularis oris and the skin of the lower lip. Its external fibres conceal the mental foramen, and are overlapped by the depressor anguli oris. Its internal fibres join with those of the opposite muscle.

The **levator menti** is a small muscle which **arises** from the incisor fossa of the lower jaw, and passing forwards, is **inserted** into the skin of the chin.

The **buccinator muscle** forms the lateral wall of the mouth, and is in series posteriorly with the constrictor muscles of the pharynx. It **arises** (1) from the alveolar arches of the upper and lower jaws, and between these attachments, from the pterygo-mandibular ligament. Its fibres are directed forwards to the angle of the mouth, where they blend with the corresponding (upper and lower) portions of

the orbicularis oris muscle. The *middle fibres* of the muscle decussate at the angle of the mouth, so as to pass, the lower set to the upper lip, the upper set to the lower lip. The buccinator is covered on its deep surface by the mucous membrane of the mouth. Superficially it is concealed by the muscles above mentioned, which converge to the angle of the mouth; it is separated from the masseter by the *suctorial pad of fat;* it is pierced by the duct of the parotid gland, and by branches of the buccal nerve.

Nerve Supply.

The facial and scalp muscles are all innervated by the **facial nerve.** The *posterior auricular branch* supplies the retrahens aurem and occipitalis; the branches forming the *pes anserinus* supply the frontalis, attollens, and attrahens aurem, the several muscles associated with the apertures of the eye, nose, and mouth (including the buccinator), and the platysma myoides.

Actions.

The almost infinite variety of facial expression is produced partly by the action of these muscles, partly by their inactivity, or by the action of antagonising muscles (antithesis). On the one hand joy is, for example, betrayed by the action of one set of muscles, while grief is accompanied by the contraction of another (opposing) set. Determination or eagerness is accompanied by a fixed expression due to a combination of muscles acting together; despair, on the other hand, is expressed by a relaxation of muscular action. For a philosophical account of the action of the facial muscles, the student should consult Darwin's *Expression of the Emotions in Man and Animals*, and Duchenne's *Mechanisme de la Physiologie humaine.*

The **platysma myoides** retracts and depresses the angle of the mouth, and depresses the lower jaw. The **occipito-frontalis,** by its anterior belly, raises the eyebrows; both bellies acting together tighten the skin of the scalp; acting along with the orbicularis palpebrarum, it shifts the scalp backwards and forwards.

The **corrugator supercilii** draws inwards the eyebrow and vertically wrinkles the forehead.

The **pyramidalis nasi** draws downwards the skin between the eyebrows, as in frowning. The upper eyelid is raised by the **levator palpebræ superioris.** The closure of the lids is effected by the **orbicularis palpebrarum,** whose fibres also assist in the lowering of the eyebrows, in the protection of the eyeball, and, by pressure on the lachrymal gland, in the secretion of tears. The **tensor tarsi,** acting along with the orbicularis palpebrarum, compresses the lachrymal sac and aids in the evacuation of its contents. The **muscles of the ear** and **nose** have quite rudimentary actions expressed by their names. Of the muscles of the mouth, the **orbicularis oris** has a complex action, depending on the degree of contraction of its component parts. It causes compression and closure of the lips in various ways, tightening the lips over the teeth, contracting them as in osculation, or causing pouting or protrusion of one or the other. The **accessory muscles** of the **lips** draw them upwards (zygomatici, levator anguli oris, levator labii superioris alæque nasi, levator labii superioris), outwards (zygomaticus major, risorius, platysma, depressor anguli oris, buccinator), and downwards (depressor anguli oris, depressor labii inferioris, platysma). The **levator menti** elevates the skin of the chin and protrudes the lower lip. The **buccinator** retracts the angles of the mouth, flattens the cheeks, and brings them in contact with the teeth.

The Fascia and Muscles of the Orbit.

The eyeball with its muscles, vessels and nerves, is lodged in a mass of soft and yielding fat which entirely fills up the cavity of the orbit. Surrounding the posterior part of the eyeball is the **capsule of Tenon,** which constitutes a large lymph space or synovial bursa in relation to the eyeball. Anteriorly the capsule is in contact with the conjunctiva, which intervenes between the latter and the eyeball; posteriorly it is pierced by and prolonged along the optic nerve. It is a smooth membrane connected to the globe of the eye by loose areolar tissue. It is pierced by the tendons of the ocular muscles, along which it sends prolongations continuous with the muscular sheaths.

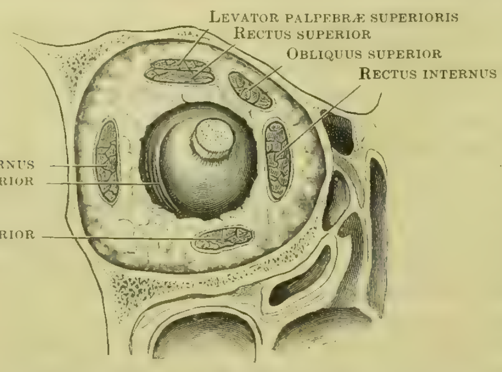


Fig. 276.—Transverse Vertical Section through the Orbit behind the Eye-ball to show the Arrangement of Muscles.

The **muscles of the orbit** are seven in number: one, the levator palpebræ superioris, belongs to the upper eyelid; the other six are muscles of the eyeball.

The **levator palpebræ superioris** lies immediately beneath the orbital periosteum over the superior rectus muscle. It has a narrow **origin** above that muscle from the margin of the optic foramen. It expands as it passes forwards, to end, in relation to the upper lid, in a membranous expansion which is **inserted** in a four-fold manner: (1) slightly into the orbicularis palpebrarum and skin of the upper lid, (2) mainly into the upper border of the tarsal cartilage, (3) slightly into the conjunctiva, and (4) by its edges into the upper border of the margin of the orbital opening.

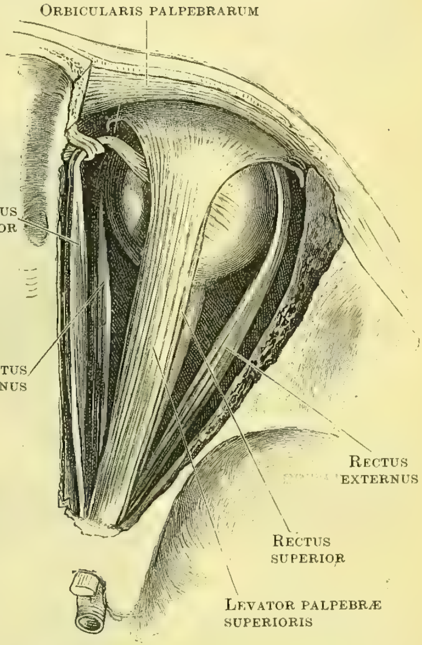


FIG. 277.—THE MUSCLES OF THE ORBIT (from above).

The **recti muscles** are four in number —**superior, inferior, internal,** and **external.** They all **arise** from a membranous ring surrounding the optic foramen, which is separable into two parts—a *superior common tendon,* giving origin to the superior and internal recti and the upper head of the external rectus; and an *inferior common tendon,* giving origin to internal and inferior recti and the lower head of the external rectus. The two origins of the external rectus muscle are separated by the passage into the orbit of the oculo-motor, nasal, and abducent nerves. Forming flattened bands which traverse the fat of the orbit around the optic nerve and eyeball, the four muscles end in tendons which pierce the capsule of Tenon, and are **inserted** into the sclerotic about eight millimetres (three to four lines) behind the margin of the cornea. The **superior** and **inferior recti** are inserted in the vertical plane slightly internal to the axis of the eyeball; the **external** and **internal recti** in the transverse plane of the eyeball; and all are attached in front of the equator of the eyeball.

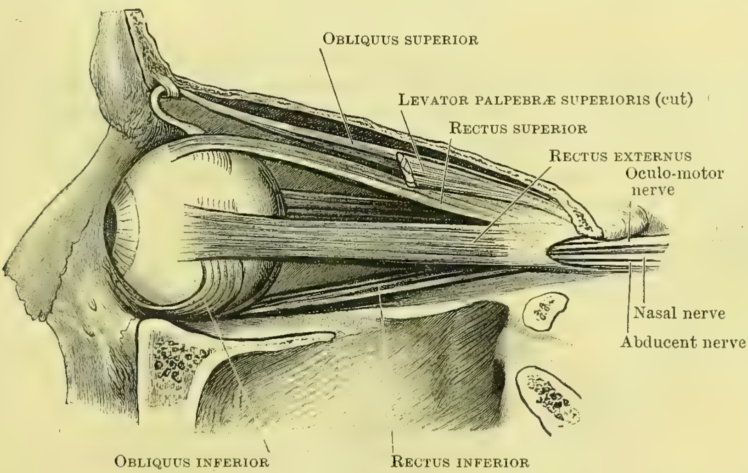


FIG. 278.—THE MUSCLES OF THE ORBIT (from without).

The **obliquus superior arises** from the margin of the optic foramen between the recti superior and internus. It passes forwards as a narrow muscular band internal to the rectus superior, and at the anterior margin of the orbit forms a narrow tendon which passes through a special fibrous pulley (trochlea) attached to the roof of the orbit. Its direction is thus altered, and passing outwards between the tendon of the superior rectus and the eyeball, it is **inserted** into the sclerotic between the superior and external recti, midway between the cornea and the entrance of the optic nerve.

The **obliquus inferior arises** from the inner side of the floor of the orbit just behind its anterior margin, and external to the naso-lachrymal groove. It forms a slender rounded slip, which curls round the inferior rectus tendon, and passes between the external rectus and the eyeball, to be **inserted** into the sclerotic between the superior and external recti, and further back than the superior oblique muscle.

Müller's muscle is a rudimentary bundle of non-striated muscular fibres bridging across the

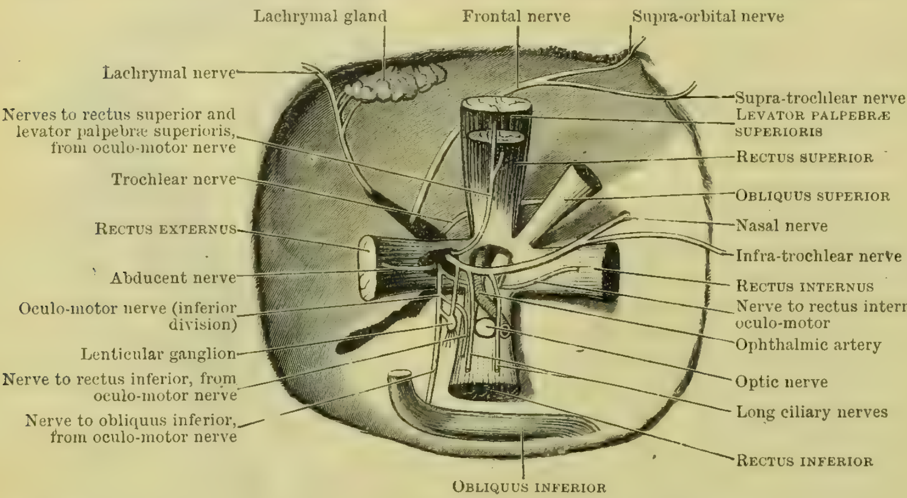


Fig. 279.—Schematic Representation of the Nerves which traverse the Cavity of the Orbit.

spheno-maxillary fissure and infraorbital groove. It is supplied by fibres from the sympathetic, and may have a slight influence in the protrusion of the eyeball.

Nerve Supply.

The muscles of the orbital cavity are supplied by the third, fourth, and sixth cranial nerves. The **fourth nerve** (trochlearis) supplies the obliquus superior; the **sixth** (abducens) supplies the rectus externus; the **third nerve** (motor oculi) supplies the others—levator palpebræ superioris, recti, superior, inferior and internus, and obliquus inferior.

Actions.

The **levator palpebræ superioris** elevates the upper eyelid and antagonises the orbicularis palpebrarum muscle. The six muscles inserted into the eyeball serve to move the longitudinal axis of the eyeball upwards, downwards, inwards, and outwards, besides causing a rotation of the eyeball on its own axis. The following table expresses the action of individual muscles. It must be remembered that, while similar movements occur simultaneously in the two eyeballs, the horizontal movements may, by adduction of the muscles of both sides, cause convergence of the axes of the two eyeballs for the purposes of near vision.

a. **Adduction**	and **Abduction.**
Rectus internus Rectus superior } Rectus inferior }	Rectus externus Obliquus superior } *(correcting* Obliquus inferior } *adductors)*
b. **Elevation**	and **Depression.**
Rectus superior Obliquus inferior	Rectus inferior Obliquus superior
c. **Rotation outwards.**	**Rotation inwards.**
Obliquus inferior	Obliquus superior Rectus superior } *(in adduction)* Rectus inferior }

Muscles of Mastication.

The muscles of mastication comprise the masseter, temporal, external and internal pterygoids, and buccinator (described above).

The **masseter arises** (1) superficially from the lower border of the zygoma in its anterior two-thirds, and (2) more deeply from the deep or inner surface of the

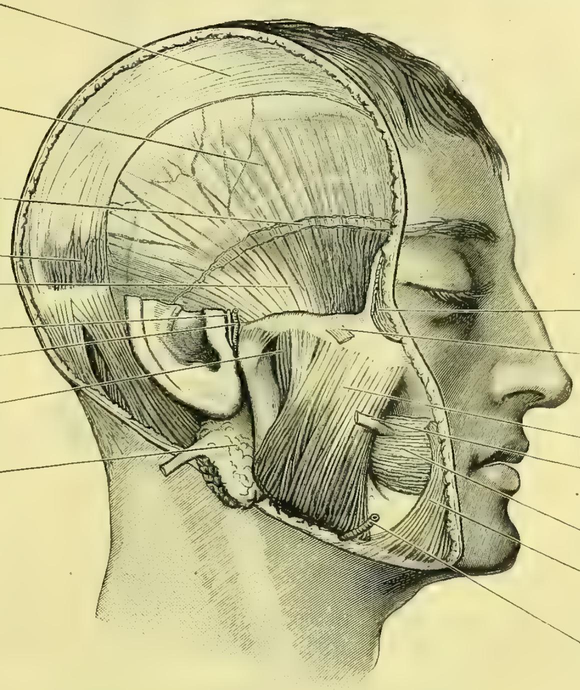


FIG. 280.—MUSCLES OF MASTICATION (superficial view).

zygoma in its whole length. The superficial fibres are directed downwards and backwards towards the angle of the jaw; the deeper fibres are directed vertically downwards. The muscle is **inserted** into the outer surface of the ramus of the lower jaw and coronoid process. The deepest fibres blend with the fibres of the subjacent temporal muscle.

The masseter muscle occupies the posterior part of the cheek. It is covered by the parotid gland, and is crossed by Stenson's duct and the branches of the facial nerve, and it conceals the lower jaw and a part of the temporal muscle.

The **temporal muscle** is a fan-shaped muscle **arising** from the whole area of the temporal fossa, as well as from the temporal fascia which covers it. Its converging fibres pass beneath the zygomatic arch. In the pterygoid region the muscle is **inserted** into the deep surface and apex of the coronoid process, and into the anterior border of the ramus of the lower jaw.

The muscle is concealed by the temporal fascia, zygoma, the masseter muscle, and the coronoid process. It crosses over the external pterygoid muscle and the internal maxillary artery.

The **external pterygoid muscle arises** by two heads, upper and lower. The upper head is attached to the under surface of the great wing of the sphenoid; the lower head takes origin from the outer surface of the external pterygoid plate. The muscle is directed outwards and backwards, to be **inserted** into (1) the depression in front of the neck of the lower jaw, and (2) the inter-articular fibro-cartilage and capsule of the temporo-maxillary articulation.

The muscle is placed deeply in the pterygoid region; being covered by the temporal muscle and coronoid process, it partially conceals the internal pterygoid muscle and the trunk and branches of the inferior maxillary nerve. The internal

maxillary artery passes over or under the muscle, and disappears between its two heads of origin.

The **internal pterygoid muscle** has likewise a double **origin**—(1) from the deep

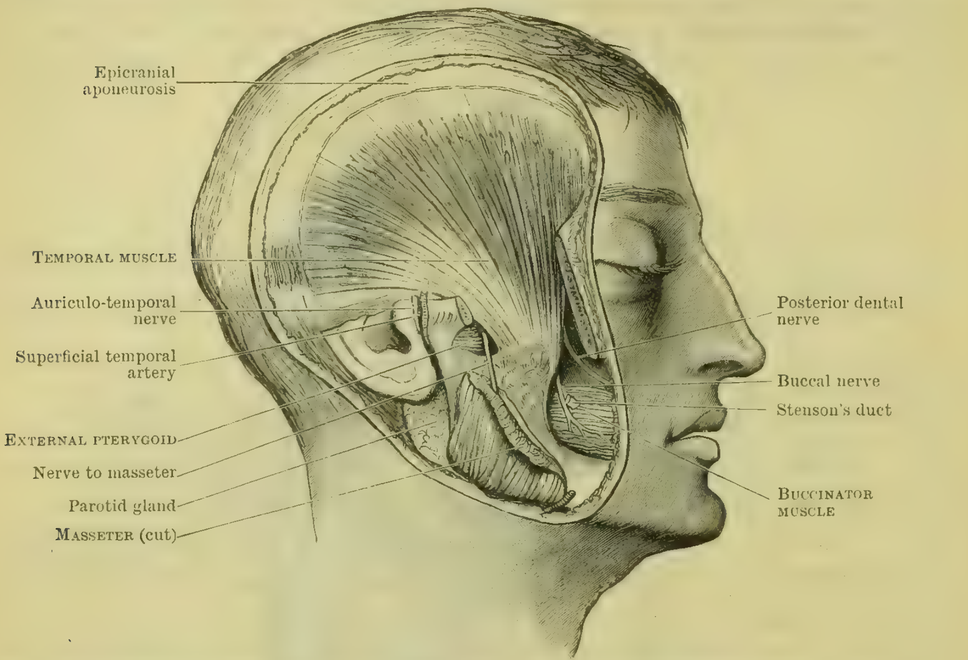


Fig. 281.—Muscles of Mastication, Deeper View (zygoma and masseter muscle removed).

surface of the external pterygoid plate, and (2) by a stout tendon from the tuberosity of the upper jaw. It is quadrilateral in form, and is directed downwards

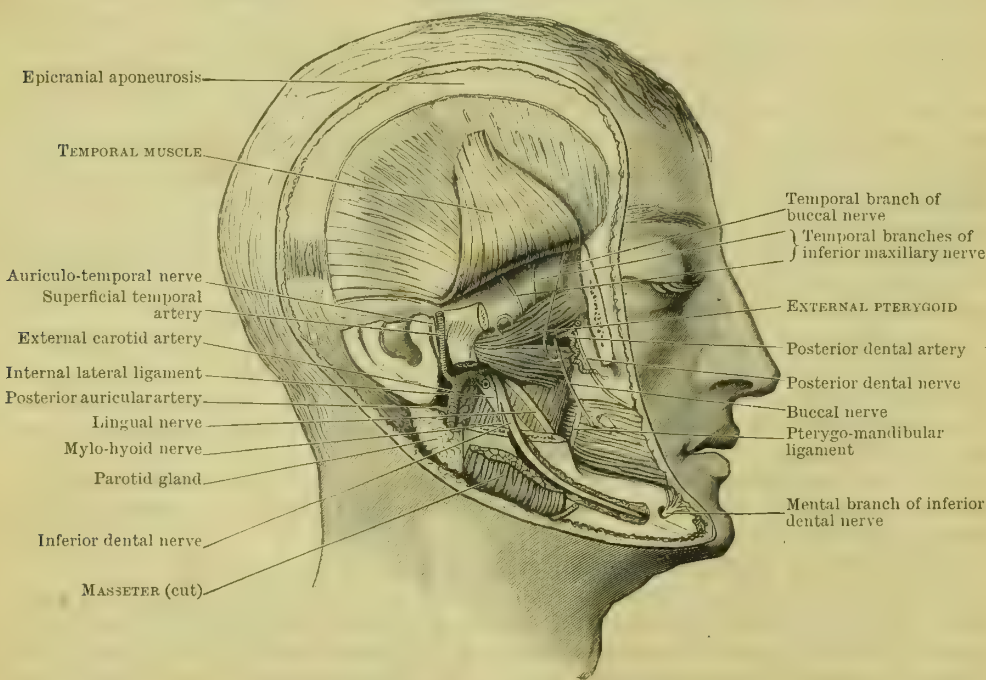


Fig. 282.—Pterygoid Region.

outwards, and backwards, to be **inserted** into a triangular impression on the inner surface of the lower jaw, between the mylo-hyoid groove and the angle of the bone.

The muscle is covered over by the external pterygoid muscle, by branches of the inferior maxillary nerve, and by the internal lateral ligament and ramus of the lower jaw. Beneath it are the Eustachian tube, muscles of the soft palate, and pharynx (superior constrictor).

Nerve Supply.

The **inferior maxillary division of the fifth nerve** supplies all the muscles of mastication except the buccinator, which is supplied by the **facial nerve.** The internal pterygoid muscle is supplied by the nerve before its division into anterior and posterior parts; the other muscles are innervated by the anterior trunk.

Actions.

The above muscles, assisted by others in the neck, produce the various movements of the lower jaw, as follows:—

a. **Opening** and	**Closure of the Jaw.**
Weight of the jaw Digastric Mylo-hyoid Genio-hyoid Genio-hyoglossus Infra-hyoid muscles	Masseter Temporal Internal pterygoid
b. **Protraction** and	**Retraction.**
External pterygoid Internal pterygoid Temporal (*anterior fibres*)	Temporal (*posterior fibres*)
c. **Lateral Movement of the Jaw.**	
External pterygoid } (*of one side*) Internal ,, }	

THE MUSCLES OF THE NECK.

The muscles in the neck include, in addition to those associated with the muscles of the back, and described already (p. 363), the following series:—(1) sterno-cleido-mastoid; (2) the muscles of the hyoid bone (supra-hyoid and infra-hyoid); (3) the muscles of the tongue (extrinsic and intrinsic); (4) the muscles of the pharynx and soft palate; and (5) the prevertebral muscles.

The **sterno-cleido-mastoid muscle** is the prominent muscle projecting on the side of the neck. It **arises** by two heads—(1) *sternal*, from the anterior surface of the manubrium sterni, and (2) *clavicular*, from the upper surface of the clavicle in its inner third. The muscle is **inserted** into the mastoid process and superior curved line of the occipital bone.

It stretches obliquely across the neck, separating the anterior and posterior triangles. Superficially it is crossed by the platysma, the external jugular vein, and some of the superficial branches of the cervical plexus. It conceals the splenius capitis, digastric, levator anguli scapulæ, scaleni and infra-hyoid muscles, the carotid sheath, the cervical plexus, and the spinal accessory nerve. The last-named nerve pierces the muscle.

The sterno-cleido-mastoid muscle is properly divisible into three parts: (1) **sterno-mastoid,** placed superficially, and passing obliquely from the sternum to the mastoid process; (2) **cleido-mastoid,** placed more deeply, and directed vertically upwards from the clavicle to the mastoid process; and (3) **cleido-occipitalis,** passing obliquely upwards and backwards behind the cleido-mastoid to the superior curved line of the occipital bone.

The sterno-mastoid muscle is innervated by the spinal accessory nerve, joined by a branch from the cervical plexus (C. 2).

The action of the muscle is referred to below.

The Muscles of the Hyoid Bone.

The **infra-hyoid muscles** comprise the omo-hyoid, sterno-hyoid, sterno-thyroid, and thyro-hyoid muscles.

The **omo-hyoid** is a double-bellied muscle, **arising** by its posterior belly from the superior border of the scapula and the suprascapular ligament. It forms a narrow muscular band, directed obliquely forwards and upwards, to end in an intermediate tendon beneath the sterno-mastoid muscle. From this tendon the anterior belly proceeds upwards to its **insertion** into the body of the hyoid bone.

The posterior belly of the muscle separates the posterior triangle into occipital and subclavian parts; the anterior belly crosses the common carotid artery at the level of the cricoid cartilage, and in the anterior triangle forms the boundary

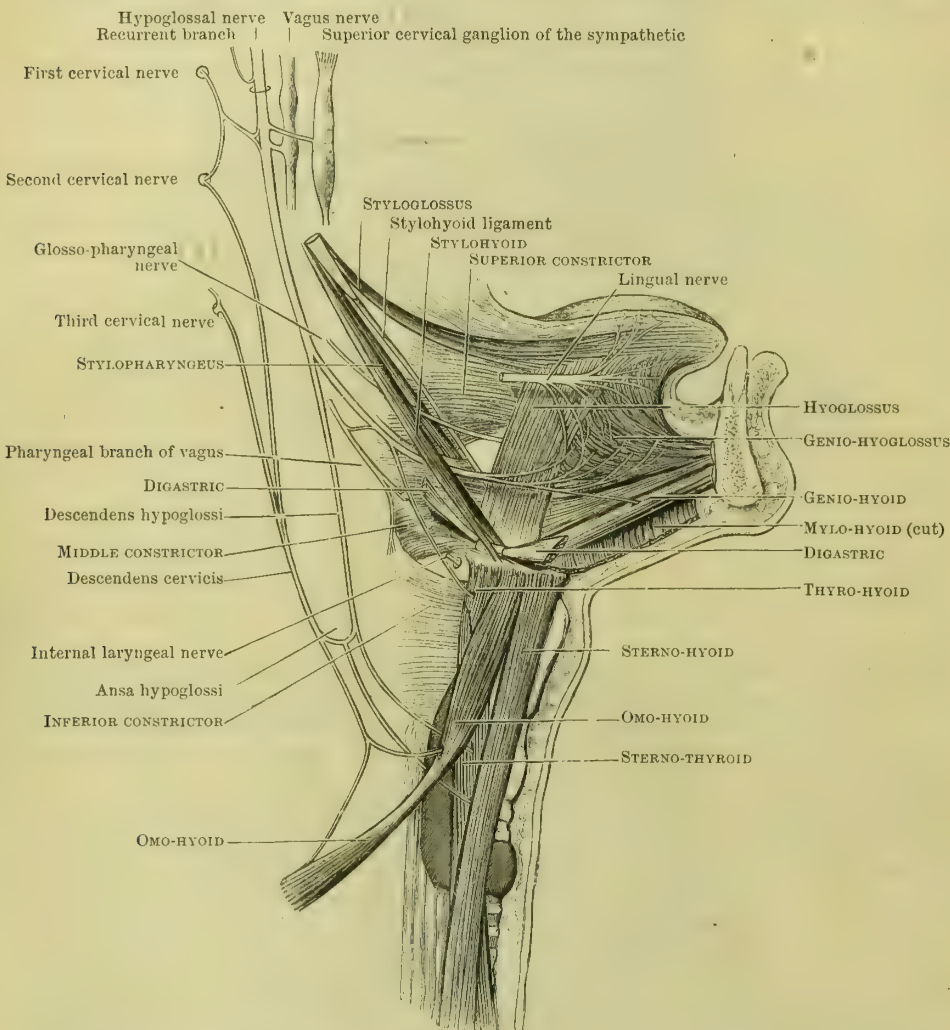


FIG. 283.—THE MUSCLES OF THE HYOID BONE AND STYLOID PROCESS, AND THE EXTRINSIC MUSCLES OF THE TONGUE, WITH THEIR NERVES.

between the muscular and carotid triangles. A process of the deep cervical fascia binds down the tendon and the posterior belly to the scapula and first rib.

The **sterno-hyoid muscle arises** from the posterior surface of the presternum, from the back of the first costal cartilage, and from the clavicle. It passes vertically upwards in the neck, internal to the omo-hyoid and in front of the sterno-thyroid muscle, to be **inserted** into the body of the hyoid bone. Except near its origin the muscle lies superficially in the anterior triangle, alongside the omo-hyoid and in front of the sterno-thyroid and thyro-hyoid muscles, the trachea, and the thyroid body.

The **sterno-thyroid muscle arises** beneath the sterno-hyoid from the back of the presternum and first costal cartilage. Broader than the preceding muscle, it

passes upwards and slightly outwards in the neck in front of the trachea and thyroid body, and beneath the omo-hyoid and sterno-hyoid muscles, to be **inserted** into the oblique line of the thyroid cartilage. The muscle is marked by an oblique tendinous intersection in the middle of its length.

The **thyro-hyoid muscle** continues the line of the preceding muscle to the hyoid bone. Short and quadrilateral, it **arises** from the oblique line of the thyroid

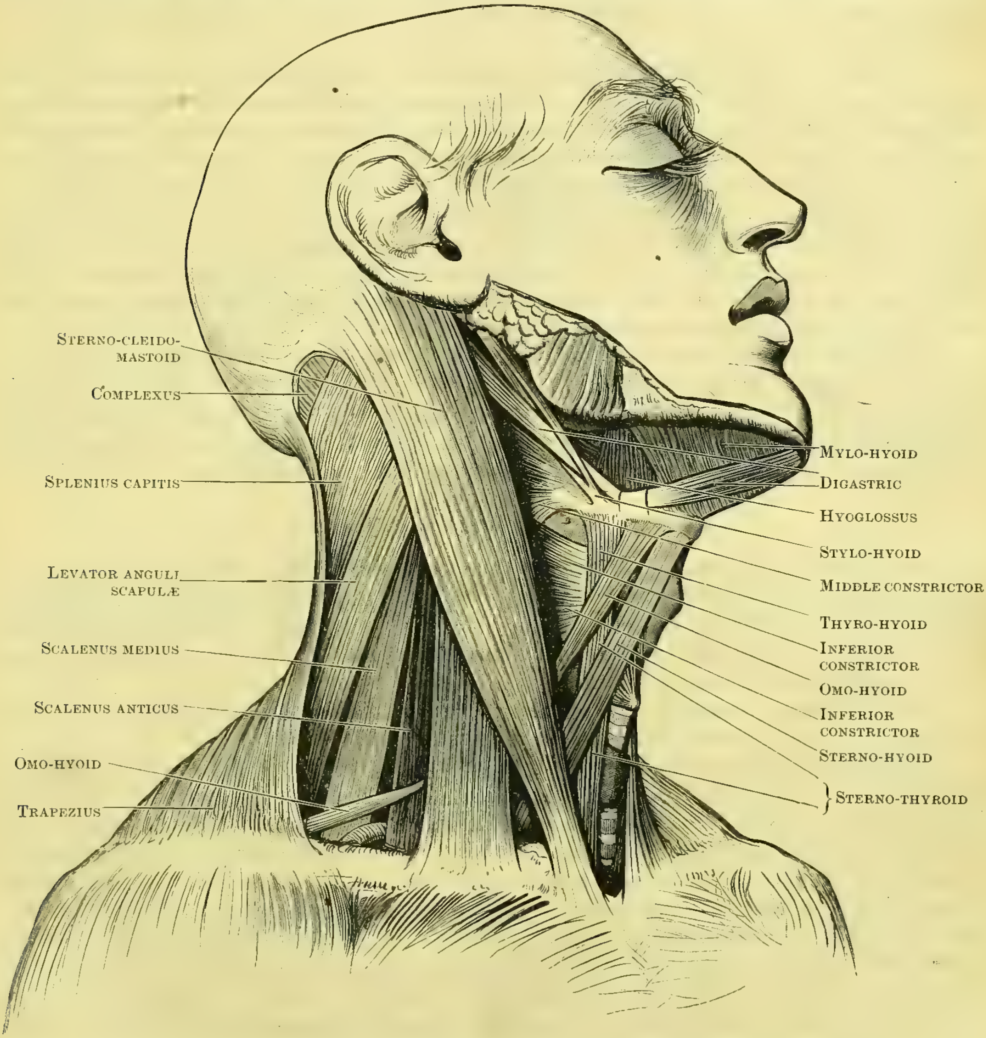


FIG. 284.—THE TRIANGLES OF THE NECK (Muscles).

cartilage, and passing over the thyro-hyoid membrane beneath the omo-hyoid and sterno-hyoid, it is **inserted** into the body of the hyoid bone.

The **levator glandulæ thyroideæ** is an occasional slip stretching between the hyoid bone and the isthmus or pyramid of the thyroid body.

The **supra-hyoid muscles** comprise the digastric, stylo-hyoid, mylo-hyoid, genio-hyoid muscles, and also the genio-hyoglossus and hyoglossus, to be described among the extrinsic muscles of the tongue.

The **digastric muscle arises** by its posterior belly from the digastric groove beneath the mastoid process. It is directed downwards and forwards to end in an intermediate tendon, which is connected by a pulley-like band of cervical fascia to the body of the hyoid bone. The anterior belly of the muscle is directed forwards and upwards to the chin, and is **inserted** into an oval impression on the lower border of the mandible close to the symphysis. The muscle forms the

boundary of the submaxillary space. The posterior belly is concealed at its origin by the mastoid process and the muscles attached to it. It crosses the carotid vessels and the hypoglossal nerve in the anterior triangle. The anterior belly covers the mylo-hyoid muscle.

The **stylo-hyoid muscle arises** from the styloid process of the temporal bone, and is **inserted** into the body of the hyoid bone by two slips which enclose the tendon of the digastric muscle. It is directed downwards and forwards alongside the posterior belly of the digastric, and crosses the anterior triangle in front of the carotid vessels.

The **mylo-hyoid muscle arises** from the lower three-fourths of the mylo-hyoid ridge of the lower jaw. It is directed downwards and inwards, to be **inserted** into the upper border of the body of the hyoid bone, and more anteriorly (along with the opposite muscle) into a median raphe extending from the hyoid bone nearly to the chin. The muscle forms a diaphragm in the floor of the mouth, and has in contact with its external surface the digastric muscle and the submaxillary gland. Its internal surface is partially covered by the mucous membrane of the floor of the mouth, and is separated from the hyoglossus and genio-hyoglossus muscles by the deep part of the submaxillary gland, the sublingual gland, Wharton's duct, and the lingual and hypoglossal nerves.

The **genio-hyoid muscle arises** from the lower of the two genial tubercles on the back of the symphysis of the lower jaw. It is directed downwards and backwards, to be **inserted** into the body of the hyoid bone. The muscle is concealed by the digastric and mylo-hyoid muscles. It lies along the lower border of the genio-hyoglossus. The muscles of opposite sides are often fused together.

The Muscles of the Tongue.

The muscular substance of the tongue consists of two symmetrical series of muscles placed on either side of a membranous raphe in the middle line, and composed of (1) **extrinsic muscles** arising from the soft palate, styloid process, hyoid bone and lower jaw, and (2) **intrinsic muscles**, proper to the tongue itself. Each set consists of four series of muscles.

The **extrinsic muscles** are four in number: (1) genio-hyo-glossus, (2) hyo-glossus, (3) stylo-glossus, and (4) palato-glossus.

The **genio-hyo-glossus muscle** (Fig. 283) is an extrinsic muscle of the tongue as well as a supra-hyoid muscle. It is a fan-shaped muscle **arising** by its apex from the upper of the two genial tubercles behind the symphysis of the lower jaw. From this origin the muscular fibres diverge; the lowest fibres are directed downwards and backwards, to be **inserted** into the body of the hyoid bone; the highest fibres curve forwards, to be attached to the tip of the tongue; the intermediate fibres are attached to the substance of the tongue between the base and tip. The muscles of opposite sides are separated by the median raphe of the tongue. On the outer side of each are placed the hyo-glossus and mylo-hyoid muscles. Between the hyo-glossus and genio-hyo-glossus are found the stylo-hyoid ligament, the lingual artery, and the glosso-pharyngeal nerve.

The **hyo-glossus muscle** is also an extrinsic muscle of the tongue as well as a supra-hyoid muscle. It **arises** from the hyoid bone (body and great cornu), and is directed upwards and forwards, to be **inserted** into the side of the tongue, interlacing with the stylo-glossus. The muscle is quadrilateral, and lies between the genio-hyo-glossus and mylo-hyoid muscles, separated from the latter by the mucous membrane of the floor of the mouth, the sublingual and part of the submaxillary glands, the lingual and hypoglossal nerves, and Wharton's duct.

The **chondro-glossus** is a small separated slip of the hyo-glossus, not always present.

The **stylo-glossus muscle arises** beneath the parotid gland from the lower end of the styloid process and from the stylo-mandibular ligament. Proceeding forwards and inwards, it is **inserted** into the side and under surface of the tongue, its fibres spreading out to decussate with those of the palato-glossus and hyo-glossus. The muscle is covered by the internal pterygoid muscle and the mucous membrane of the tongue.

The **palato-glossus** is a thin sheet of muscular fibres **arising** from the under surface of the soft palate, where it is continuous with fibres of the opposite muscle. It passes downwards in the anterior pillar of the fauces, and spreads out, to be **inserted** into the sides of the tongue, blending with the stylo-glossus and the deep transverse fibres of the tongue. The muscle is placed directly beneath the mucous membrane of the soft palate and tongue.

Intrinsic Muscles of the Tongue.—Besides receiving the fibres of insertion of the extrinsic muscles, the substance of the tongue is composed of four intrinsic muscles on either side, two in the sagittal plane, the superior and inferior linguales; two in the coronal plane, the transverse and vertical fibres.

The **superior lingualis muscle** extends from base to tip of the tongue, placed on its dorsum immediately under the mucous membrane, into which many of its fibres are inserted.

The **inferior lingualis** is a cylindrical band of muscular fibres occupying the under part of the organ on each side, in the interval between the genio-hyo-glossus and the hyo-glossus muscles. Posteriorly some of its fibres extend to the hyoid bone.

The **transverse fibres** arise from the median raphe, and radiate outwards to the dorsum and sides of the tongue, decussating with the extrinsic muscles and the fibres of the vertical muscle. They occupy the substance of the tongue between the superior and inferior linguales.

The so-called **vertical fibres** arise from the dorsal surface of the tongue, and sweep downwards and outwards to its sides, intermingled with the fibres of the previous muscle and the insertions of the extrinsic muscles. These two muscles form a very considerable part of the total muscular substance of the organ.

Nerve Supply.

The muscles of the hyoid bone and of the tongue are for the most part supplied by the **ansa cervicalis** (C. 1. 2. 3.) and by the **hypoglossal nerve**. A few of the muscles are supplied by the trigeminal, facial, and spinal accessory nerves.

Muscles.	Nerves.	Origin.
Omo-hyoid		
Sterno-hyoid	Ansa cervicalis . . .	C. 1. 2. 3.
Sterno-thyroid		
Thyro-hyoid		
Genio-hyoid		C. 1. 2.
Genio-hyo-glossus		
Hyo-glossus	Hypoglossal . .	
Stylo-glossus		XII.
Intrinsic muscles of tongue . .		
Palato-glossus	Pharyngeal plexus . .	XI.
Mylo-hyoid	Mylo-hyoid branch of inferior dental nerve .	V.
Digastric		
Anterior belly		
Posterior belly	Facial	VII.
Stylo-hyoid		

Actions.

These muscles of the neck have a complexity of muscular action, owing to their numerous attachments to more or less movable points. The movements for which they are responsible in whole or part are (1) movements of the hyoid bone in mastication and deglutition, (2) movements of the thyroid cartilage, (3) movements of the tongue, (4) movements of the head, (5) movements of the shoulder, and (6) respiration.

(1) Movements of the Hyoid Bone.—The hyoid bone is elevated or depressed, and moved forwards or backwards along with the lower jaw and tongue, in speech, mastication, and swallowing.

a. **Elevation** and **Depression.**		*b.* **Protraction** and **Retraction.**	
Digastric	Thyro-hyoid	Genio-hyoid	Stylo-hyoid
Stylo-hyoid	Sterno-hyoid	Genio-hyo-glossus	Middle constrictor
Mylo-hyoid	Omo-hyoid		
Genio-hyoid	Sterno-thyroid		
Genio-hyo-glossus			
Hyo-glossus			
Muscles closing the mouth			

(2) **Movements of the Thyroid Cartilage.**—The thyroid cartilage is raised and lowered during speech and deglutition.

Elevation.	**Depression.**
Thyro-hyoid	Sterno-thyroid
Stylo-pharyngeus	Crico-thyroid
Palato-pharyngeus	Depressors of hyoid bone
Elevators of hyoid bone	
Muscles closing mouth	

(3) **Movements of the Tongue.**—The chief movements of the tongue in speech and deglutition are elevation and depression, protrusion and retraction, and lateral movements.

a. **Elevation** and	**Depression.**
Stylo-glossus (base)	Genio-hyo-glossus
Palato-glossus	Hyo-glossus
Muscles elevating hyoid bone	Chondro-glossus
Muscles closing mouth	Muscles depressing the hyoid bone

b. **Protrusion** and	**Retraction.**
Genio-hyo-glossus (*posterior fibres*)	Genio-hyo-glossus (*anterior fibres*)
	Stylo-glossus
c. **Lateral Movements.**—The muscles of one side only.	

(4) **Movements of the Head.**—The sterno-mastoid muscles, acting together, flex the head on the spinal column, assisted by the supra-hyoid and infra-hyoid muscles. The sterno-mastoid muscle of one side, acting alone, bends the head to the same side, and simultaneously rotates it to the opposite side, as seen in *torticollis* (wryneck).

(5) **Movements of the Shoulder Girdle.**—The omo-hyoid and sterno-mastoid muscles have already been included among the elevators of the shoulder girdle.

(6) **Respiration.**—The muscles on the front of the neck are auxiliary muscles in extraordinary or difficult inspiration. The masseter and temporal muscles fix the lower jaw; the hyoid bone is raised and fixed by the supra-hyoid muscles; and the sternum is raised by the sterno-mastoid and infra-hyoid muscles.

The Muscles of the Pharynx.

The muscular envelope of the pharynx is composed of two strata. The *external layer* consists of the three constrictor muscles; the *internal layer* consists of the longitudinal fibres of the stylo-pharyngeus and palato-pharyngeus muscles.

The **superior constrictor muscle** is triangular or fan-shaped. It **arises** successively from the lower half of the posterior border of the internal pterygoid plate, from the pterygo-mandibular ligament, from the mylo-hyoid ridge of the lower jaw, and from the mucous membrane of the floor of the mouth (*glosso-pharyngeus*). The muscular fibres radiate backwards, and are **inserted** for the most part into a median raphe extending down the back wall of the pharynx in

the middle line. The highest fibres are attached to the pharyngeal spine of the occipital bone, and the lowest fibres are overlapped by the middle constrictor. A crescentic interval occurs above the muscle, below the base of the skull, in which the Eustachian tube and the levator and tensor palati muscles appear. The lower border of the muscle is separated from the middle constrictor by the stylo-pharyngeus muscle and the glosso-pharyngeal nerve. It separates the internal carotid artery from the cavity of the pharynx and tonsil.

The **middle constrictor muscle arises** from the stylo-hyoid ligament and both cornua of the hyoid bone. From its origin the muscular fibres radiate backwards, to be **inserted** into the median raphe on the posterior aspect of the pharynx. The upper fibres overlap the lower part of the superior constrictor; the lower fibres are concealed from view by the inferior constrictor muscle. In the interval between the middle and inferior constrictors are found the internal laryngeal artery and nerve.

The **inferior constrictor muscle arises** from the oblique line of the thyroid cartilage, and from the side of the cricoid cartilage. Its fibres radiate backwards, to be **inserted** into the median raphe on the back of the pharynx, the upper fibres overlapping the lower part of the middle constrictor, the lower fibres blending with the muscular fibres of the œsophagus. Below the lower border of the muscle the inferior laryngeal artery and nerve enter into relation with the larynx.

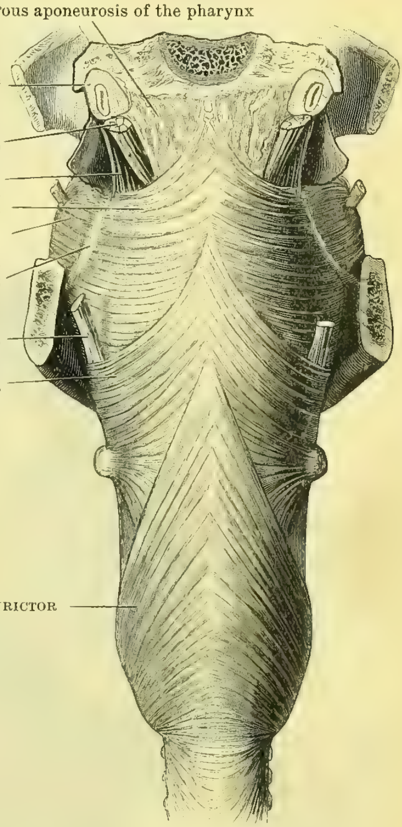


Fig. 285.—Posterior View of the Pharynx and Constrictor Muscles.

The **deeper longitudinal stratum** of muscles in the pharyngeal wall is composed of the insertions of the stylo-pharyngeus and palato-pharyngeus.

The **stylo-pharyngeus muscle arises** from the root of the styloid process on its inner side, and passing downwards between the carotid arteries, it enters the wall of the pharynx in the interval between the superior and middle constrictor muscles. Spreading out beneath the middle constrictor muscle, it is **inserted** into the superior and posterior borders of the thyroid cartilage and into the wall of the pharynx itself, becoming continuous posteriorly with the palato-pharyngeus. In the neck the glosso-pharyngeal nerve crosses it.

The **palato-pharyngeus** occupies the soft palate and the pharyngeal wall. In the substance of the soft palate it consists of two layers, a postero-superior layer, thin, and continuous across the middle line with the corresponding layer on the opposite side, and an antero-inferior layer, which is thicker, and is attached to the posterior border of the hard palate. The levator palati and azygos uvulæ muscles are enclosed between the two layers, which unite at the posterior edge of the palate, receiving at the same time additional fibres arising from the Eustachian tube (salpingo-pharyngeus). The muscle descends to the pharynx in the posterior pillar of the fauces. Its fibres spread out in the form of a thin sheet in the wall of the pharynx, in continuity anteriorly with the stylo-pharyngeus, and are **inserted** into the posterior border of the thyroid cartilage, and behind that into the aponeurosis of the pharynx, reaching down as far as the lower border of the inferior

constrictor. The muscle is placed beneath the middle and inferior constrictors in the pharyngeal wall, and the fibres of the muscles of opposite sides decussate in the middle line beneath the median raphe.

The Muscles of the Soft Palate.

The muscular fold of the soft palate and uvula is composed of five pairs of muscles on each side, attached to the skull, hard palate, pharynx, and tongue—the palato-pharyngeus (and salpingo-pharyngeus), azygos uvulæ, levator palati, tensor palati, and palato-glossus.

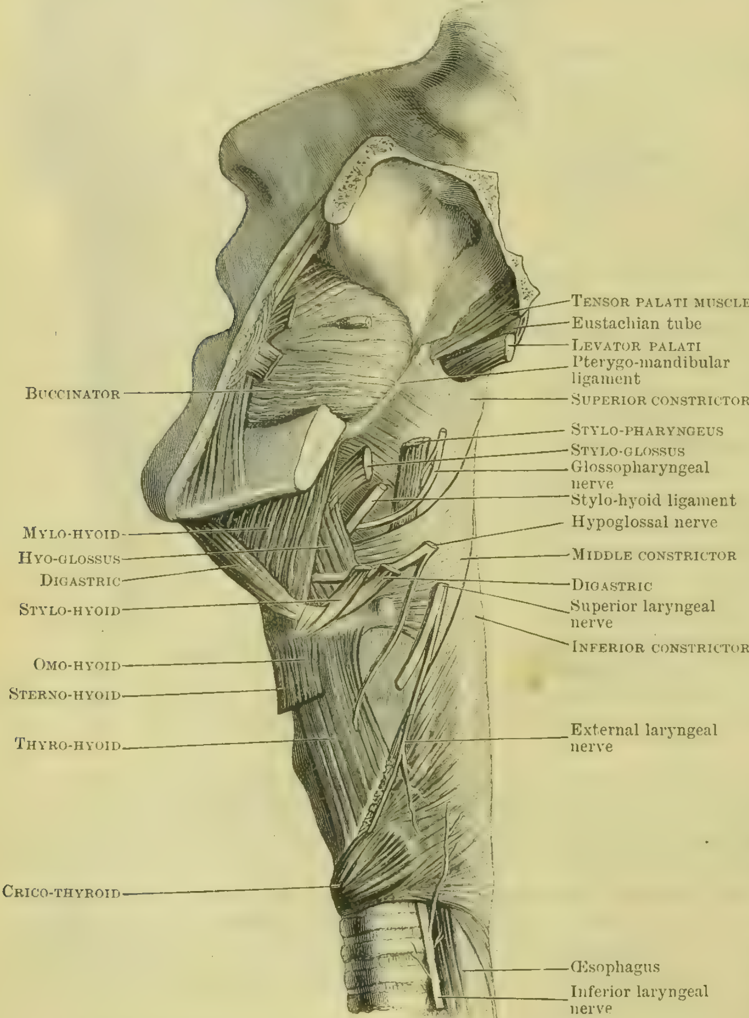


Fig. 286.—Lateral View of the Wall of the Pharynx.

The **palato-pharyngeus** muscle has been already described (p. 389) among the muscles of the pharynx.

The **azygos uvulæ** consists of two narrow bundles enclosed, along with the insertion of the levator palati, between the layers of the palato-pharyngeus. The slips **arise** from the posterior nasal spine and the aponeurosis of the soft palate, and unite as they proceed backwards to end in the uvula.

The **levator palati** has a double **origin**: (1) from the under surface of the apex of the petrous portion of the temporal bone, and (2) from the lower part of the cartilaginous Eustachian tube. It passes obliquely downwards and inwards, across the upper border of the superior constrictor muscle, and afterwards between the two layers of the palato-pharyngeus muscle to enter the soft palate, into the aponeurosis of which it is **inserted**. Some of its fibres become continuous with those of the opposite muscle. It is separated from the tensor palati by the Eustachian tube and the deeper layer of the palato-pharyngeus muscle.

The **tensor (circumflexus) palati arises** from the scaphoid fossa and the alar spine of the sphenoid bone, and from the outer side of the cartilaginous Eustachian tube. It descends between the internal pterygoid muscle and the internal pterygoid plate, and ends in a tendon which hooks round the hamular process, and is

inserted beneath the levator palati into the posterior border of the hard palate, and into the aponeurosis of the soft palate.

The **palato-glossus muscle** occupying the under surface of the soft palate and the anterior pillar of the fauces, has already been described with the muscles of the tongue (p. 382).

Nerve Supply.

The chief nerve supply of the muscles of the pharynx and soft palate is the **spinal accessory nerve**, aided by the **fifth** (otic ganglion) and the **ninth** (glosso-pharyngeal) nerves and the laryngeal branches of the **vagus nerve**.

Muscles.	Nerves.	Origin.
Constrictors of pharynx, Palato-glossus, Palato-pharyngeus, Levator palati, Azygos uvulæ	Pharyngeal plexus	XI.
Tensor palati	Otic ganglion	V.
Stylo-pharyngeus	Glosso-pharyngeal	IX.
Inferior constrictor	External laryngeal, Inferior laryngeal	X.

Actions.

The muscles of the pharynx and soft palate are chiefly brought into action in **the act of swallowing**. This act is divided into a *voluntary stage*, in which the bolus lies in front of the pillars of the fauces, and an *involuntary stage*, during which the food passes from the mouth through the pharynx. The movements occurring during the passage of food through the mouth are as follows: the cheeks are compressed by the action of the buccinator muscles; the tongue, hyoid bone, and thyroid cartilage are successively raised upwards by the action of the muscles which close the mouth and elevate the hyoid bone. By these means the food is pushed backwards between the pillars of the fauces.

At the same time, by the contraction of the palato-glossus and palato-pharyngeus, the pillars of the fauces are narrowed, while the muscles of the soft palate, contracting, tighten the soft palate, and by bringing it in contact with the posterior wall of the pharynx, shut off the upper (nasal) portion of the cavity. The elevation of the tongue, hyoid bone, and larynx simultaneously raise the epiglottis and the opening of the glottis, which is closed by the approximation of the arytenoid cartilages and the combined action of laryngeal muscles (arytenoideus, thyro-arytenoideus, and thyro-aryteno-epiglottideus). The food thus slips over the posterior surface of the epiglottis and the closed opening into the larynx, and between the pillars of the fauces on either side, to the pharynx. It is now clasped by the constrictor muscles, which, by frequent contractions, force it down into the œsophagus. The contraction of the constrictor muscles results in a flattening of the pharynx and elevation of its anterior attachments.

During swallowing the tensor palati, besides stretching the soft palate, is generally regarded as opening the Eustachian tube. It has been held, on the other hand, that the Eustachian tube is closed during swallowing by the compression of its wall by the contraction of the levator palati.

Lateral and Prevertebral Muscles of the Neck.

Three series of muscles are comprised in this group: (1) vertebro-costal (scaleni, anticus, medius, and posticus), (2) vertebro-cranial (recti capitis antici, major and minor, and lateralis), and (3) vertebral (longus colli).

The **scalenus anticus arises** from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ, and descends behind the carotid sheath, to be **inserted** into the scalene tubercle and ridge on the first rib. In front of the muscle are the subclavian and internal jugular veins, and the nerves descending through the neck. Behind, it is separated from the scalenus medius by the cords of the brachial plexus, the subclavian artery, and the pleura.

The **scalenus medius arises** from the posterior tubercles of the transverse processes of the cervical vertebræ, from the second to the sixth. It descends in the floor of the posterior triangle, to be **inserted** into the rough impression on the first rib behind the subclavian artery. The muscle is covered anteriorly by the cords of the brachial plexus, subclavian artery, and omo-hyoid muscle, and is in contact behind with the levator anguli scapulæ and the scalenus posticus. It is pierced by the posterior scapular and posterior thoracic nerves.

The **scalenus posticus** arises from the posterior tubercles of the fourth, fifth, and sixth cervical transverse processes, and is **inserted** into the rough impression on the outer side of the second rib. It is concealed behind by the levator anguli scapulæ, and is in contact anteriorly with the scalenus medius.

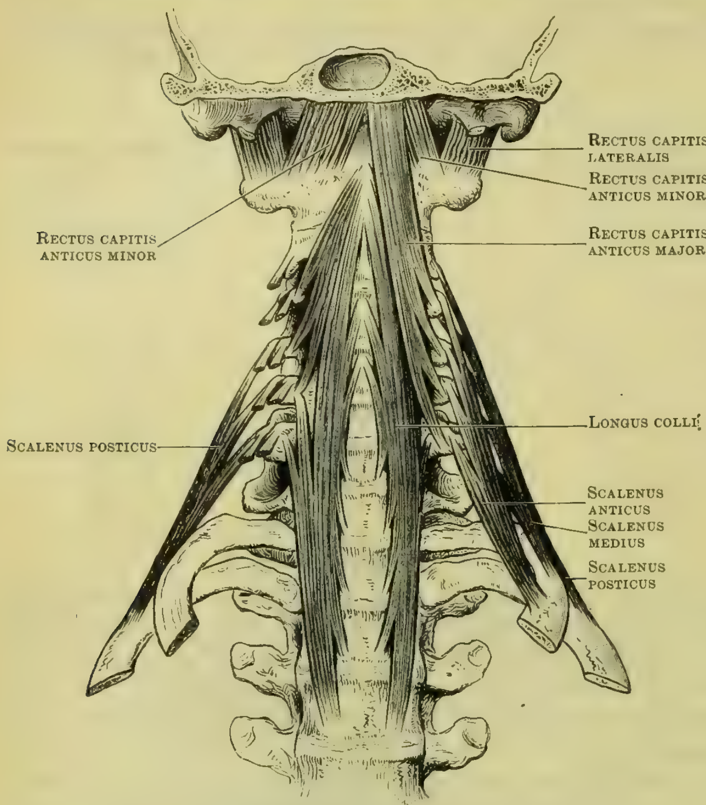


Fig. 287.—The Prevertebral Muscles of the Neck.

The **rectus capitis anticus major** arises from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ. It forms a flat triangular muscle, which is directed upwards, to be **inserted** into the basilar process of the occipital bone behind the pharyngeal spine. It lies on the cervical vertebræ behind the carotid vessels and the pharynx, external to the longus colli, and internal at its origin to the scalenus anticus.

The **rectus capitis anticus minor** arises from the anterior arch of the atlas, and

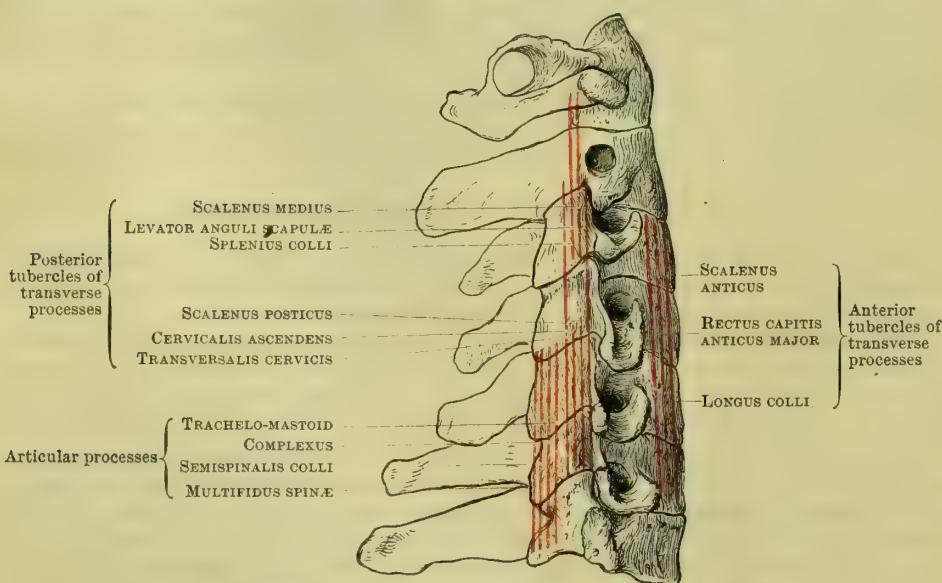


Fig. 288.—Scheme of Muscular Attachments to Cervical Vertebræ.

is **inserted** into the basilar process between the previous muscle and the foramen magnum. It is concealed by the rectus capitis anticus major.

The **longus colli** is a flattened muscular band extending from the third thoracic vertebra to the atlas. It is divisible into three portions — a vertical, a lower oblique, and an upper oblique portion.

The **vertical portion** of the muscle **arises** from the bodies of the first three thoracic and the last three cervical vertebræ; and passing vertically upwards, is **inserted** into the bodies of the second, third, and fourth cervical vertebræ.

The **lower oblique portion arises** from the bodies of the first three thoracic vertebræ, and is **inserted** into the anterior tubercles of the fifth and sixth cervical vertebræ.

The **upper oblique portion arises** from the anterior tubercles of the transverse processes of the third, fourth, and fifth cervical vertebræ, and is directed upwards, to be **inserted** into the anterior tubercle of the atlas.

The longus colli clothes the front of the vertebral column in the neck, and is separated by the deep cervical fascia from the carotid vessels, pharynx, and œsophagus.

The **rectus capitis lateralis**, in series with the posterior inter-transverse muscles in the neck, **arises** from the transverse process of the atlas, and is **inserted** into the under surface of the ex-occipital bone. It is placed alongside the recti capitis antici, separated from them by the anterior primary division of the first cervical nerve.

Nerve Supply.

The prevertebral muscles are all supplied by anterior primary divisions of the **cervical spinal nerves**: the rectus capitis anticus minor, and rectus capitis lateralis, by the loop between the first two nerves; the rectus capitis anticus major by the first four; the longus colli by the second, third, and fourth; the scaleni by the lower four or five cervical nerves.

Actions.

The movements produced by these muscles are considered along with those of other muscles acting on the head, spinal column, and thorax.

THE MUSCLES OF THE THORAX.

Muscles of Respiration.

The muscles which complete the boundaries of the thorax are the diaphragm and intercostal muscles (external and internal), along with three series of smaller muscles—the triangularis sterni, the levatores costarum, and the infracostales.

The **intercostal muscles** are arranged in eleven pairs, forming thin layers filling up the intercostal spaces.

The **external muscle arises** from the sharp lower border of the rib, and is directed downward and forward, to be **inserted** into the outer edge of the upper border of the rib below. It extends from the tubercle of the rib behind nearly to the costal cartilage in front. The *anterior intercostal aponeurosis* is continuous with it anteriorly, and extends forwards to the side of the sternum.

The **internal muscle arises** from the costal cartilage and the inner edge of the subcostal groove, and is directed downwards and backwards, to be **inserted** into the inner edge of the upper border of the rib and costal cartilage below. It extends from the side of the sternum in front to the angle of the rib behind, where it becomes continuous with the *posterior intercostal aponeurosis* extending to the tubercle of the rib.

The external intercostal muscles are covered by the pectoral muscles, serratus magnus and the muscles of the back; the internal muscles are in contact with the pleura. The intercostal vessels and nerve lie between the two muscles posteriorly.

The **levatores costarum** are in series with the external intercostal muscles. They are twelve small slips **arising** from the transverse processes of the seventh cervical and upper eleven thoracic vertebræ. They spread out in

a fan-like manner as they descend, to be **inserted** into the outer surface of the ribs posterior to the angles. They lie under cover of the longissimus dorsi muscle.

The **infra-costales** (subcostales) are slips of muscles found on the inner surface of the lower ribs near their angles. They are in series with the internal intercostal muscles, but pass over the deep surface of several ribs.

The **triangularis sterni** (m. transversus thoracis) occupies the posterior aspect of the anterior thoracic wall. It **arises** from the back of the ensiform cartilage and mesosternum as high as the level of the third costal cartilage. From this origin its fibres radiate outwards, the lower ones horizontally, the upper ones obliquely upwards, to be **inserted** into the costal cartilages of all the true ribs

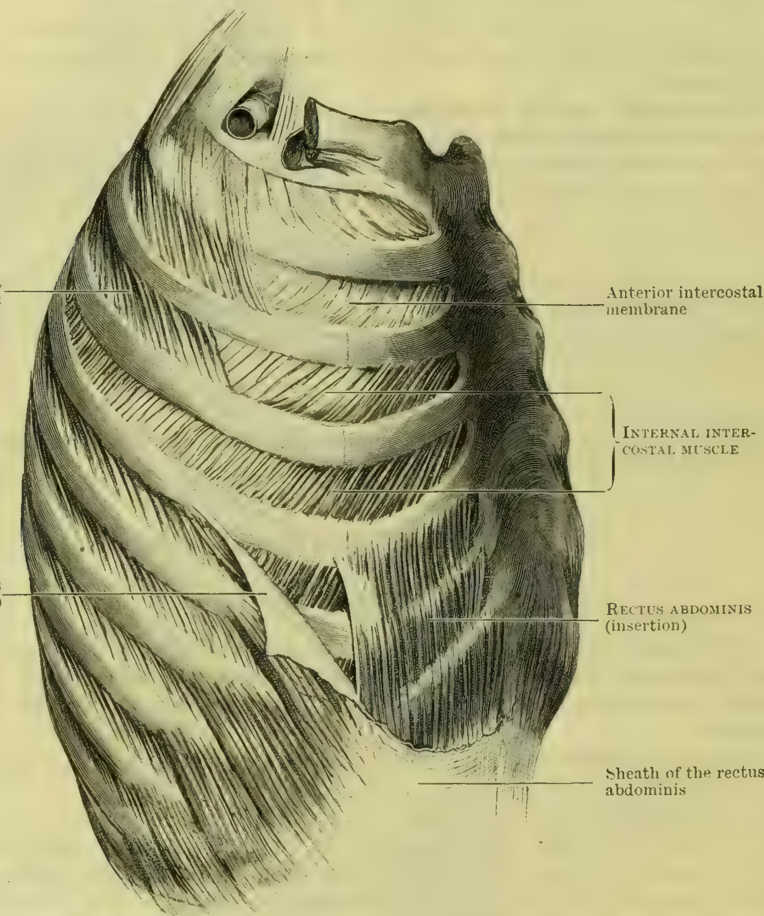


Fig. 289.—The Muscles of the Thoracic Wall.

except the first and seventh. The muscle lies against the pericardium and pleura. It is separated from the chest-wall by the internal mammary vessels and the anterior branches of the intercostal nerves. The muscle is continuous below with the transversalis abdominis.

The **diaphragm** is the great membranous and muscular partition separating the cavities of the thorax and abdomen. It forms a thin lamella arching over the liver, stomach, and spleen, with its convex upper surface in contact with the pericardium, pleura and chest-wall. It possesses a peripheral origin from the sternum, ribs and vertebral column, and an insertion into a central tendon. It **arises** (1) *anteriorly* from the posterior surface of the ensiform cartilage by two slender fleshy slips, directed backwards; (2) *laterally*, from the deep surface of the lower six ribs on each side by fleshy bands which interdigitate with those of the transversalis abdominis; (3) *posteriorly*, from the lumbar vertebræ, by the crura,

and from the arcuate ligaments. The **crura** are two elongated fibro-muscular bundles which arise from the front of the bodies of the lumbar vertebræ, on the right side from the first three, on the left side from the first two vertebræ. They are directed upwards, and passing in front of the aorta, decussate across the middle line in front of that vessel, the fibres of the right crus passing in front of those of the left crus. The fibres then encircle the œsophagus, forming an elliptical opening for its passage, and finally join the central tendon, after a second decussation in front of the gullet.

The **arcuate ligaments** are five in number.

The **middle arcuate ligament** is a fibrous arch connecting together the crura of the diaphragm in front of the aorta, and giving origin to fibres which join the crura as they decussate to encircle the gullet.

The **internal arcuate ligament** is a thickening formed by the attachment of the psoas fascia to the body of the first lumbar vertebra internally and its transverse process externally. Stretching across the upper end of the psoas muscle, the

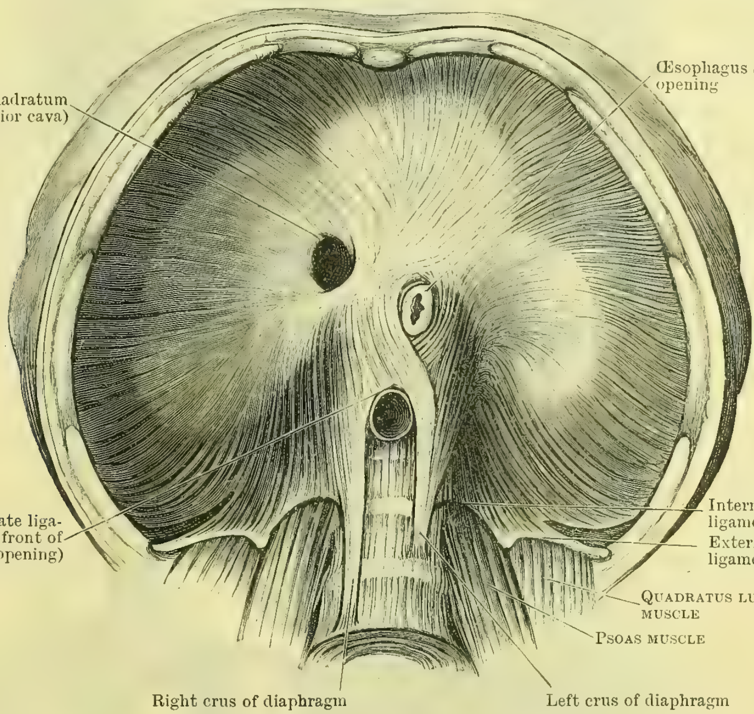


Fig. 290.—The Diaphragm (from below).

ligament gives origin to muscular fibres directed upwards on each side of the crura.

The **external arcuate ligament** is the thickened upper end of the fascia over the quadratus lumborum (anterior layer of the lumbar fascia), and is attached internally to the transverse process of the first lumbar vertebra, and externally to the last rib. It gives origin to another broad band of muscular fibres, separated from those arising from the internal arcuate ligament by an interval, and passing upwards to the central tendon of the diaphragm.

From this extensive origin the muscular fibres of the diaphragm converge to an **insertion** into a large trilobed **central tendon**. Of its lobes the right one is the largest, the middle or anterior intermediate in size, and the left the smallest. It does not occupy the centre of the muscle, being placed nearer the front than the back. The fibres of the crura are consequently the longest; those from the sternum the shortest.

The diaphragm is pierced by numerous structures. The superior epigastric artery enters the sheath of the rectus abdominis between its sternal and costal

origins; the musculo-phrenic artery passes between the attachments to the seventh and eighth ribs. The sympathetic cord and the splanchnic nerves pierce or pass behind the diaphragm; the last thoracic nerve passes beneath the external arcuate ligament; and the aorta, the vena azygos major and thoracic duct pass between the crura, beneath the middle arcuate ligament (*aortic opening*). The special foramina are two in number. The *foramen quadratum* in the right lobe of the central tendon transmits the inferior vena cava, and small branches of the right

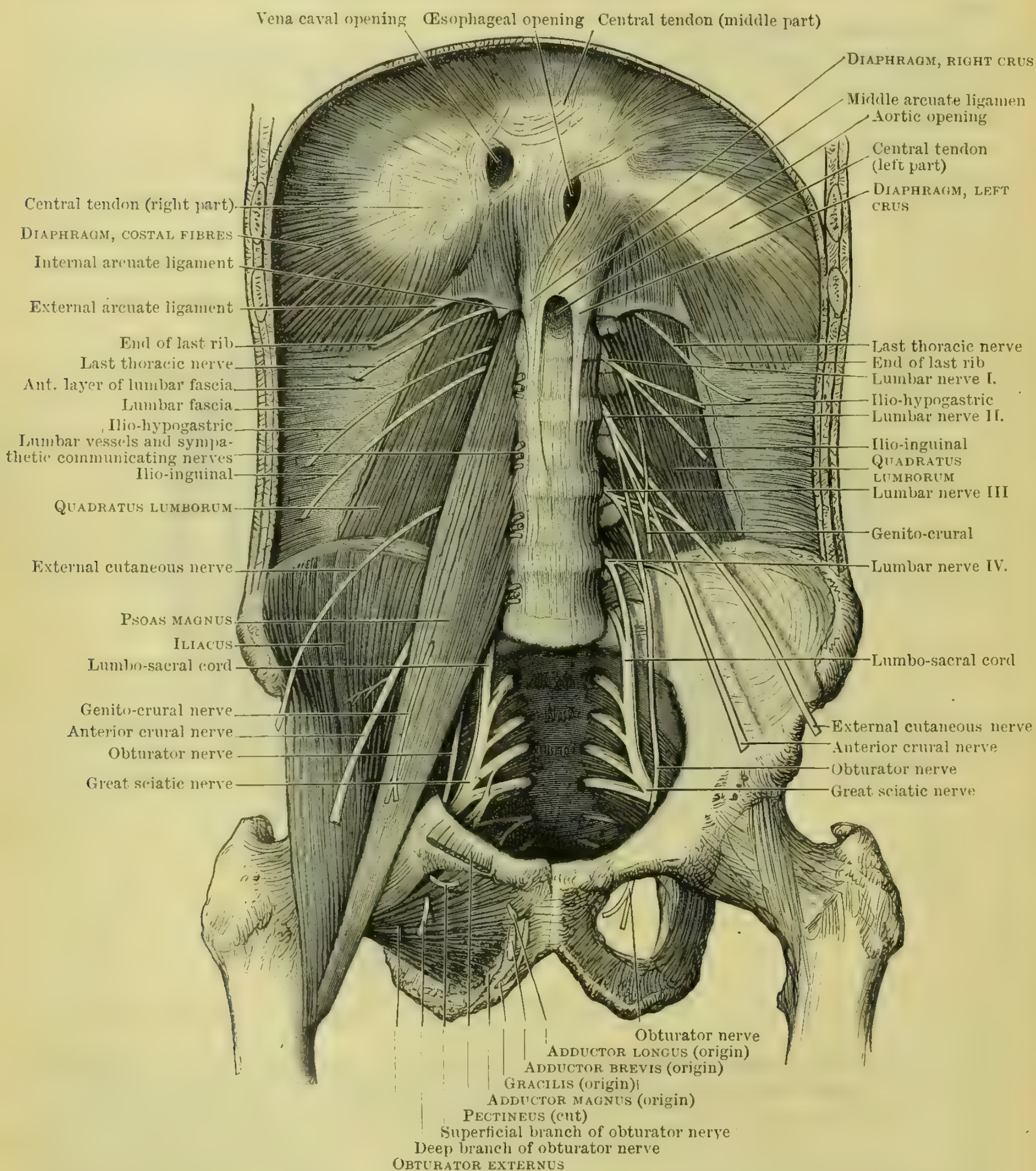


FIG. 291.—VIEW OF THE POSTERIOR ABDOMINAL WALL, TO SHOW THE MUSCLES AND THE NERVES OF THE LUMBO-SACRAL PLEXUS.

phrenic nerve. The *œsophageal opening* is in the muscular substance of the diaphragm, behind the central tendon, and is surrounded by a sphincter-like arrangement of the crural fibres. Besides the œsophagus, this opening transmits the two pneumogastric nerves. The upper convex surface of the diaphragm forms the sloping floor of the thorax, and is in contact with the pleuræ, and the pericardium (which is firmly bound down to the central tendon, and less firmly to the

muscular fibres on the left side). By its lateral margins the diaphragm is in contact with the thoracic wall beyond the reflection of the pleura, and behind with the œsophagus and descending thoracic aorta. The under surface of the diaphragm is concave, and is for the most part invested by peritoneum. It is in relation with the liver, stomach, spleen, kidneys, suprarenal bodies, duodenum and pancreas, the inferior vena cava, and the branches of the cœliac axis. Its vault is higher on the right side than on the left, owing to the upward projection of the liver on that side.

The diaphragm is found as a complete septum between the thorax and abdomen only in mammals. It is occasionally deficient in the human subject, producing *hernia of the diaphragm*, either into the pericardial cavity through the central tendon, or into the thoracic cavity through the lateral portions of the muscle. A rare condition is congenital deficiency of a part of the lateral half of the muscle, generally placed posteriorly, and on the left side. This produces, by continuity of the peritoneum and pleura behind the diaphragm, a *congenital diaphragmatic hernia.*

Nerve Supply.

The intercostal muscles, levatores costarum, infra-costal muscles, and triangularis sterni, are all supplied by the anterior primary divisions of the **intercostal nerves.** The diaphragm receives its chief, if not its entire, motor supply from the **phrenic nerves** (C. 3. 4. 5.). It is innervated also by the diaphragmatic plexus of the sympathetic, and is said to receive fibres from the lower intercostal nerves.

Actions.

The act of respiration consists of two opposite movements, inspiration and expiration.

1. The **movement of expiration** is performed by (1) the elasticity of the lungs, (2) the weight of the chest walls, (3) the elevation of the diaphragm, (4) the action of muscles—triangularis sterni and muscles of the abdominal wall. It is sometimes stated that the interosseous fibres of the internal intercostal muscles are depressors of the ribs.

2. The **movement of inspiration** (the elevation and forward movement of the sternum, and the elevation and eversion of the ribs) produces enlargement of the thoracic cavity antero-posteriorly and transversely. Its vertical diameter is increased by the descent of the diaphragm.

The muscles of **inspiration** are divided into two series—ordinary and accessory.

a. **Ordinary Muscles.**	*b.* **Extraordinary and Accessory Muscles.**
Diaphragm	Quadratus lumborum
Intercostals	Pectorales
Scaleni	Serratus magnus
Serrati postici	Sterno-mastoid
Levatores costarum	Latissimus dorsi
	Infra-hyoid muscles
	Extensors of the spine

Of the ordinary muscles, the diaphragm is the most important. Its action is twofold—**centrifugal,** elevating the ribs and increasing the transverse and antero-posterior diameters of the thorax, and **centripetal,** drawing downwards the central tendon and increasing the vertical diameter of the thorax. Of the two movements the former is the more important. There has been considerable diversity of opinion regarding the action of the intercostal muscles. It is generally agreed that the external muscles elevate the ribs; it is probable that the whole of each internal muscle acts in the same way, although it has been stated by different observers that the whole internal muscle is a depressor; or that the interosseous part is a depressor, the inter-chondral portion of the muscle an elevator of the ribs.

FASCIÆ AND MUSCLES OF THE ABDOMINAL WALL.

The space between the margins of the bony thorax and the pelvis is filled up by a series of muscles, covered externally and internally by fasciæ. The muscles are in three series—anterior, lateral, and posterior. The anterior muscles are the pyramidalis and rectus abdominis; the lateral muscles are the obliqui, externus and internus, and the transversalis abdominis; the posterior muscles are the quadratus lumborum, and the psoas (magnus and parvus) and iliacus (described already).

FASCIÆ.

The fasciæ of the abdominal wall are—*externally*, the superficial and deep fasciæ; *internally*, the fascia transversalis, continuous with the diaphragmatic, lumbar, psoas, iliac, and pelvic fasciæ, and lined within by the **extra-peritoneal tissue.**

The **superficial fascia** of the abdomen is liable to contain a large quantity of fat. It is separated in the groin into *two layers*: a superficial fatty layer continuous over Poupart's ligament with the fascia of the front of the thigh, and a deeper membranous layer attached to the inner half of Poupart's ligament, and more externally to the fascia lata of the thigh below Poupart's ligament. The two layers are separated by the lymphatic glands and the superficial vessels of the groin. Higher up in the abdominal wall the two layers blend together, and traced downwards over the spermatic cord, they unite to form the fascia and dartos muscle of the scrotum. The attachment of the fascia to the groin prevents the passage into the thigh of extravasated fluid in the abdominal wall.

The **deep fascia** of the abdominal wall resembles similar fasciæ in other situations. It forms an investment for the obliquus externus muscle, and becomes thin and almost imperceptible in relation to the aponeurosis of that muscle.

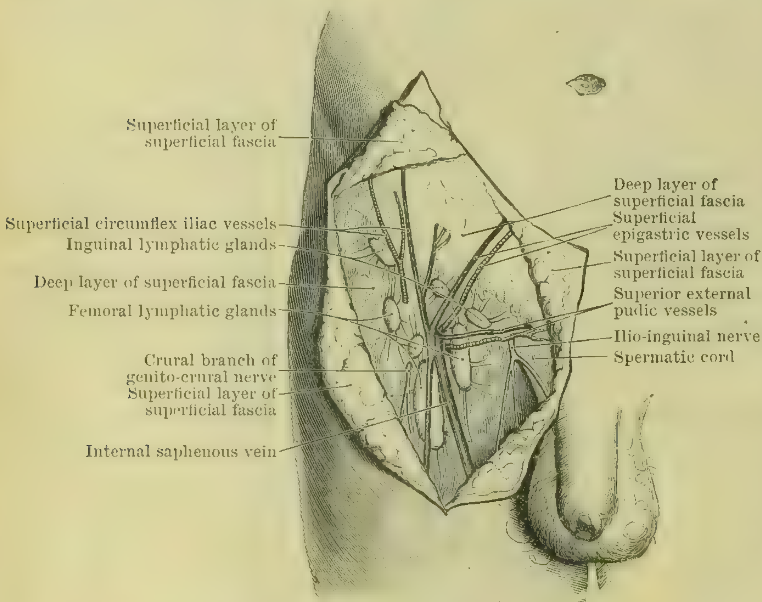


FIG. 292.—THE GROIN. STRUCTURES BETWEEN THE LAYERS OF THE SUPERFICIAL FASCIA.

The **fascial lining** of the abdominal cavity **(fascia transversalis)** consists of a continuous layer of membrane which receives different names in different parts of its extent. It covers the deep surface of the transversalis muscle, and is continuous internally (through the lumbar fascia) with the fasciæ of the quadratus lumborum and the psoas. It is continuous above with the diaphragmatic fascia, and below (the iliac crest and Poupart's ligament intervening) with the fascia iliaca. Along with the last-named fascia it forms the **femoral sheath.** It is pierced by the spermatic cord or round ligament at the internal abdominal ring, and forms the **infundibuliform fascia.** It is lined internally by the peritoneum, from which it is separated by a thick layer of **extra-peritoneal tissue.**

The extra-peritoneal layer of tissue is usually loaded with fat; it envelops the kidneys, ureters, supra-renal capsules, abdominal aorta and inferior vena cava and their branches, and forms sheaths for the vessels and ducts (ureter, vas deferens, etc.). It is continuous upwards into the thorax through the aortic opening in the diaphragm, and below is in continuity with a similar tissue in the pelvis. It not only completely invests the kidneys and suprarenal capsules, but it also becomes interpolated between the layers of peritoneum upholding and enveloping the intestines. This tissue is absent in relation to the diaphragm.

THE MUSCLES OF THE ABDOMINAL WALL.

The **lateral muscles** comprise the obliquus externus, obliquus internus, and transversalis abdominis.

The **obliquus externus abdominis** is a broad thin sheet of muscle, with an **origin** from the outer surfaces of the lower eight ribs, by slips which interdigitate with the serratus magnus and latissimus dorsi muscles. The muscular fibres radiate downwards and forwards, the lowest fibres passing vertically downwards, to be **inserted** directly into the outer lip of the iliac crest in its anterior half or two-thirds. The rest of the muscle is inserted into an extensive triangular aponeurosis covering the anterior abdominal wall. This aponeurosis is broader below than above; it is united with part of the aponeurosis of the obliquus internus in the upper three-fourths of its extent, to form the anterior layer of

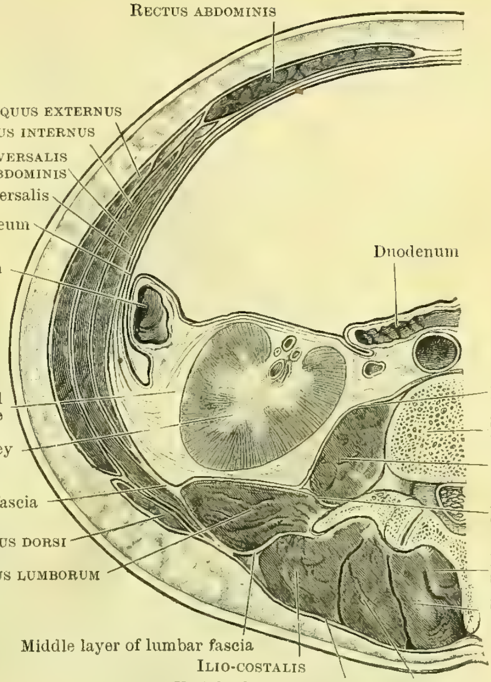


FIG. 293.—TRANSVERSE SECTION THROUGH THE ABDOMEN, OPPOSITE THE SECOND LUMBAR VERTEBRA.

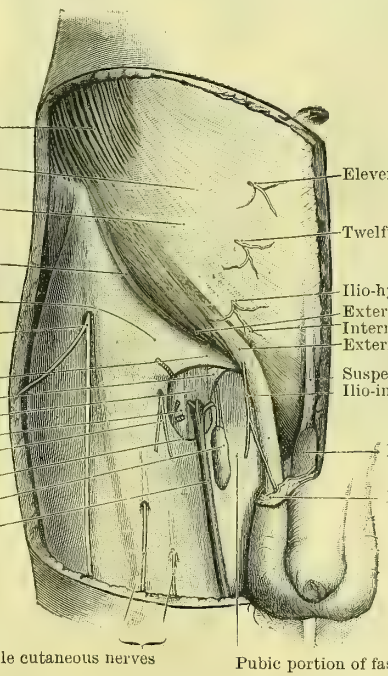


FIG. 294.—THE GROIN. THE STRUCTURES SEEN ON REMOVAL OF THE SUPERFICIAL FASCIA.

the **sheath of the rectus muscle.** It thus gains an attachment, above to the ensiform cartilage, below to the symphysis pubis, and by its intermediate fibres to the **linea**

alba, a broad interlacing band of fibres which occupies the middle line of the anterior abdominal wall in its whole extent, and forms the greater part of the ultimate insertion of the lateral abdominal muscles.

The upper part of the aponeurosis on the chest-wall covers the rectus abdominis muscle, and gives origin to fibres of the pectoralis major. Below it gives rise to

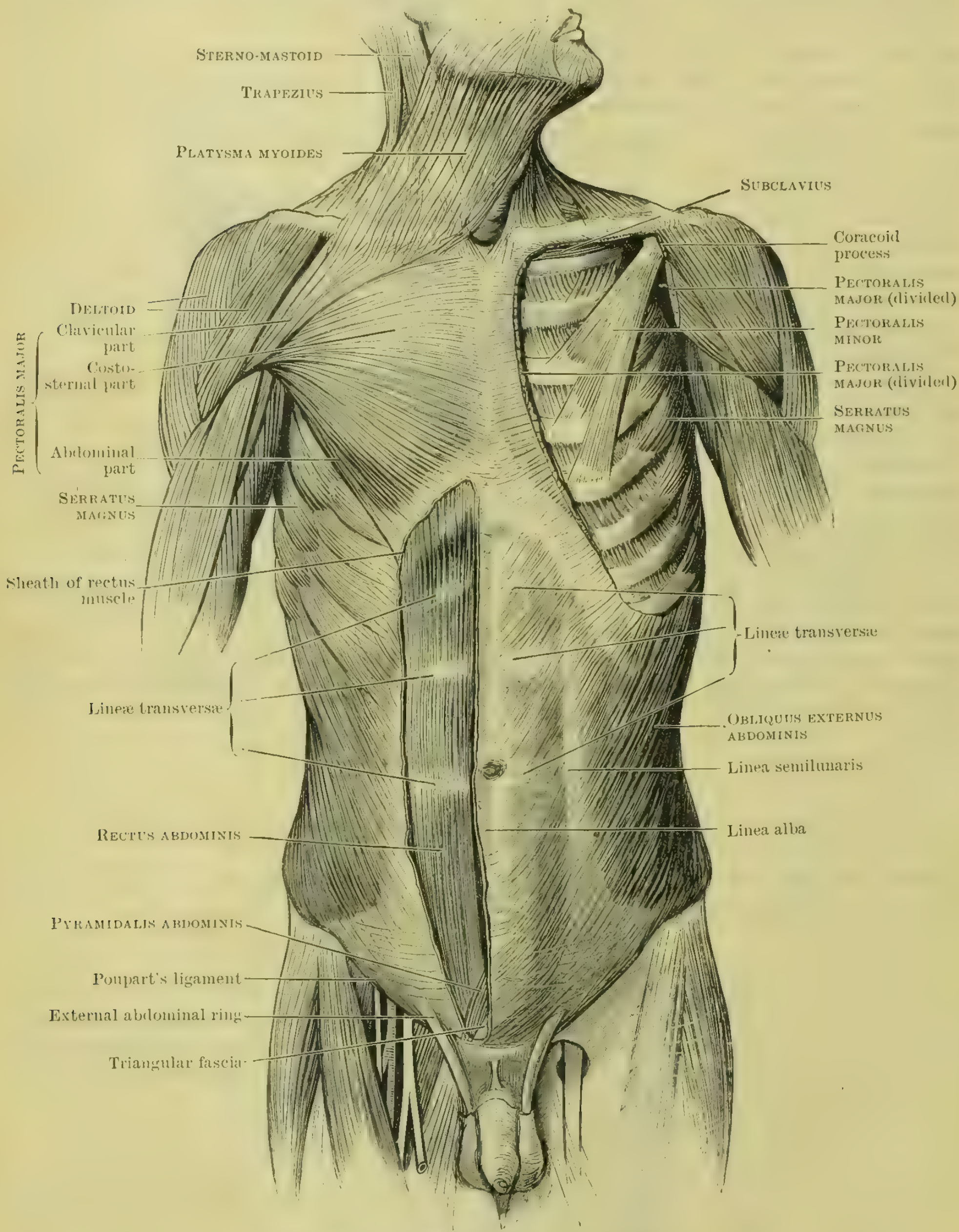


Fig. 295.—Anterior Muscles of the Trunk.

Poupart's ligament, Gimbernat's ligament, the external abdominal ring with its two pillars, the intercolumnar fascia and fibres, and the triangular fascia.

Poupart's ligament is an arched fascial band which extends from the anterior superior iliac spine to the spine of the pubis, over the iliacus, psoas, and pectineus muscles. It represents the lower limit of the aponeurosis of the obliquus externus abdominis, and gives attachment below to the fascia lata of the thigh. Its outer part affords partial origin to the deeper lateral muscles of the abdominal wall,

and attaches the fascia transversalis and fascia iliaca; the inner part forms the floor of the inguinal canal. At its inner end a triangular band of fibres is reflected horizontally backwards to the ilio-pectineal line, forming **Gimbernat's ligament**, the outer edge of which limits internally the **crural ring**. The femoral vessels in the femoral sheath enter the thigh beneath Poupart's ligament, in front of the psoas muscle.

The **external abdominal ring**, the place of exit of an inguinal hernia, is a split in the aponeurosis of the obliquus externus, just above the spine of the pubis. It transmits the spermatic cord, or round ligament of the uterus, covered by the cremaster muscle or cremasteric fascia. The opening is of considerable extent, and its edges are drawn together by a thin fascia, strengthened superficially by a number of arched and horizontal fibres, the **intercolumnar fibres**, which arise from Poupart's ligament and sweep inwards across the cleft in the aponeurosis.

The margins of the ring constitute its pillars. The **external pillar** is narrow, and is formed from that part of the aponeurosis which joins the pubic spine, and is continuous with the inner end of Poupart's ligament. The **internal pillar** is the part of the aponeurosis internal to the ring which is attached to the crest and symphysis of the pubis. It is flat and broad.

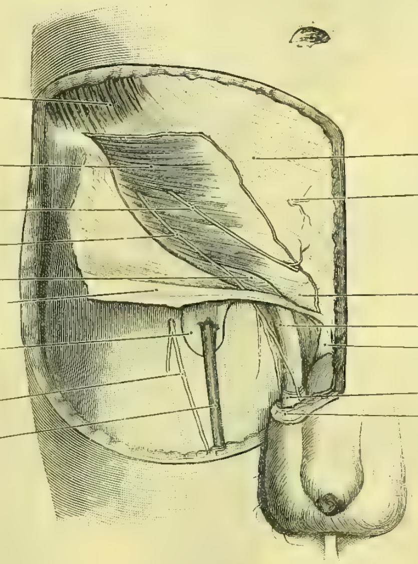


FIG. 296.—THE GROIN. The structures seen on removal of part of the obliquus externus.

The intercolumnar fibres and the pillars of the external abdominal ring are continuous with a thin tubular sheath, the **intercolumnar** or **external spermatic fascia**, which forms an envelope for the spermatic cord or round ligament beyond the external abdominal ring.

The **triangular fascia**, lastly, is a triangular band of fibres placed behind the internal pillar of the external abdominal ring. It consists of fibres from the *opposite* external oblique aponeurosis, which, having traversed the linea alba, gain an insertion into the crest and spine of the pubis on the opposite side.

The obliquus externus muscle is superficial in almost its whole extent. It is overlapped posteriorly by the latissimus dorsi muscle, but may be separated from it just above the iliac crest by an angular interval (triangle of Petit).

The **obliquus internus abdominis**, a broad thin sheet lying between the obliquus externus and the transversalis, **arises** from (1) the lumbar fascia, (2) the anterior half of the iliac crest, and (3) the outer half of Poupart's ligament. Directed for the most part upwards and forwards, its highest fibres are **inserted** directly into the last three ribs. The rest of the fibres form an extensive aponeurosis, broader above than below, which splits along the **linea semilunaris**, to form, along with the aponeuroses of the obliquus externus and transversalis muscles, the **sheath of the rectus**, and is thereafter inserted into the seventh, eighth, and ninth costal cartilages, and into the linea alba from the ensiform cartilage to the symphysis pubis. The fibres arising from Poupart's ligament join with those of the transversalis muscle having a similar origin to form the **conjoint tendon**, which passes altogether in front of the rectus muscle, to be attached to the pubic crest and spine and to the ilio-pectineal line.

The obliquus internus is limited above by the costal arch. Its lower fibres, arching over the spermatic cord, assist in forming, externally, the anterior wall of the inguinal canal; internally, by means of the conjoint tendon, its posterior wall.

Its lowest fibres are continued into the **cremaster muscle**, prolonged along the spermatic cord, through the inguinal canal.

The **cremaster muscle** may be said to have an **origin** from the lower border of the obliquus internus, and from the middle of Poupart's ligament. It forms a thin sheet, enveloping the testicle and spermatic cord; its fibres are arranged in loops which arch over the cord, and are **inserted** into the fascia, and to a less extent (uppermost fibres) into the pubic spine. The muscle is more largely represented by fascia in the female, and constitutes the **cremasteric fascia.**

The **transversalis muscle arises** (1) from the under surface of the costal cartilages of the lower six ribs, interdigitating with the origins of the diaphragm; (2) from the lumbar fascia; (3) from the anterior half of the inner lip of the iliac crest; and (4) from the outer third of Poupart's ligament. The muscular fibres

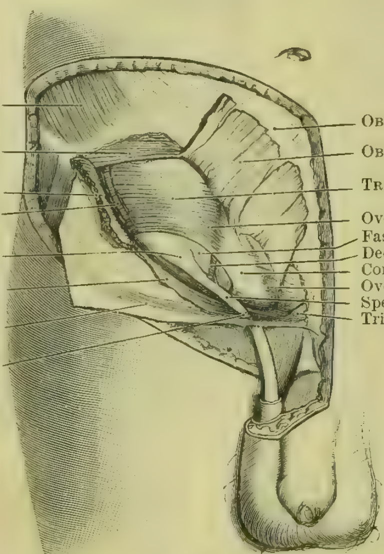


Fig. 297.—The Groin. The structures seen on reflexion of part of the obliquus internus.

are directed for the most part horizontally forwards, and end in an aponeurosis which has a twofold **insertion.** (1) After forming (along with the aponeurosis of the obliquus internus) the posterior layer of the sheath of the rectus, the aponeurosis is attached to the ensiform cartilage and linea alba. (2) The lower fibres of the muscle are joined by the lower part of the obliquus internus to form the **conjoint tendon**, which passes in front of the lower part of the rectus muscle, to be inserted into the crest and spine of the pubis and the ilio-pectineal line.

The transversalis muscle is separated by the lower intercostal nerves from the obliquus internus muscle, and is lined on its deep surface by the transversalis fascia. Its lower border forms a concave edge, separated from Poupart's ligament by a lunular interval filled by the transversalis fascia, through which the spermatic cord emerges at the internal abdominal ring, under cover of the obliquus internus muscle.

The **anterior muscles** of the abdominal wall include the pyramidalis and rectus abdominis, enveloped by the rectus sheath, on either side of the linea alba.

The **pyramidalis abdominis** is a small triangular muscle **arising** from the pubic

crest in front of the rectus muscle. It is directed obliquely upwards, to be **inserted** for a variable distance into the linea alba. The muscle is often absent.

The **rectus abdominis muscle** is broad and strap-like, and **arises**, by an inner and an outer head, from the symphysis and crest of the pubis. Expanding as it passes upwards, the muscle is **inserted** into the front of the ensiform cartilage, and into the fifth, sixth, and seventh costal cartilages. On its anterior surface are three or more transverse tendinous intersections (**lineæ transversæ**), adherent to the sheath of the muscle; the lowest opposite the umbilicus, and the highest about the level of the costal arch. Enclosed in its sheath, and covered anteriorly by the pyramidalis muscle, the rectus conceals the superior and deep epigastric arteries, the terminal branches of the lower thoracic nerves (which pierce the muscle to reach the anterior abdominal wall), the fold of Douglas, and the fascia transversalis. The inner border of the muscle lies alongside the linea alba; its outer border is convex, and forms the **linea semilunaris**.

The **sheath of the rectus muscle** is derived from the aponeuroses of the lateral muscles of the abdominal wall, which, after enclosing the muscle, give rise to the linea alba in the middle line. At the linea semilunaris, at the outer border of the rectus muscle, the aponeurosis of the obliquus internus splits into anterior and posterior layers. The anterior layer, joined by the aponeurosis of the obliquus externus, passes in front of the rectus, and constitutes the anterior lamina of the sheath. The posterior layer, joined by the aponeurosis of the transversalis muscle, passes behind the rectus, and constitutes the posterior lamina of its sheath. This arrangement obtains in the upper three-fourths of the abdominal wall. Below the level of the iliac crest the sheath of the muscle is deficient posteriorly, and a crescentic border, the **fold of Douglas**, marks the lower limit of the posterior lamina. In consequence, the rectus in the lower fourth of the abdominal wall rests upon the fascia transversalis directly. Close examination, however, usually reveals a thin layer behind the muscle in continuity with the fold of Douglas, and merging below with the fascia transversalis. In this region the rectus is covered anteriorly by the conjoint tendon, and by the aponeurosis of the obliquus externus, which is gradually becoming separate from the subjacent aponeurosis. The upper part of the rectus, lying on the chest-wall, is only covered anteriorly by a single layer of aponeurosis derived from the obliquus externus, which in this situation is giving origin to the pectoralis major muscle.

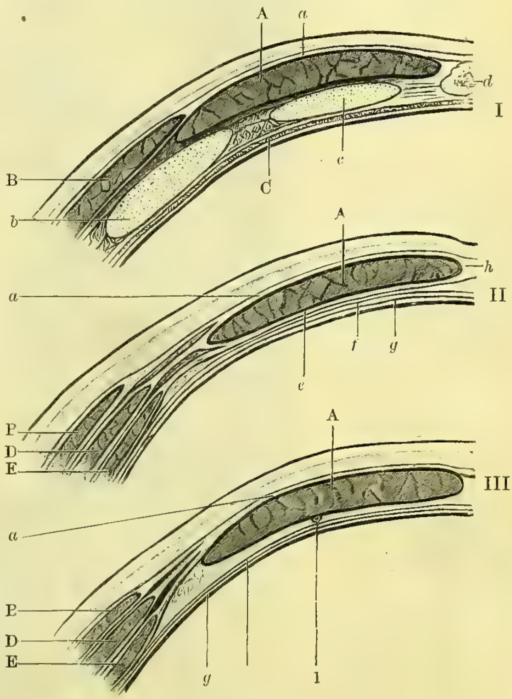


FIG. 298.—THE SHEATH OF THE RECTUS ABDOMINIS MUSCLE.

(I.), In the thoracic wall; (II.), In the upper three-quarters of the abdominal wall; (III.), In the lower fourth of the abdominal wall.

A, RECTUS MUSCLE; B, OBLIQUUS EXTERNUS; C, DIAPHRAGM; D, OBLIQUUS INTERNUS; E, TRANSVERSALIS ABDOMINIS. *a*, Anterior layer of rectus sheath; *b*, Fifth costal cartilage; *c*, Sixth costal cartilage; *d*, Xiphoid cartilage; *e*, Posterior layer of rectus sheath; *f*, Transversalis fascia; *g*, Peritoneum; *h*, Linea alba. 1, Deep epigastric artery.

Inguinal Canal.—These muscles of the abdominal wall form the boundaries of the inguinal canal, which transmits the spermatic cord in the male and the round ligament in the female through the lower part of the abdominal wall. The canal begins at the internal abdominal ring, placed half an inch above Poupart's ligament, and midway between the anterior superior iliac spine and the symphysis pubis. It ends at the external abdominal ring, placed above the spine and crest

of the pubis. The *front wall* of the canal is formed by the aponeurosis of the obliquus externus, and in its outer part by the muscular fibres of the obliquus internus; the *back wall* of the canal is formed by the fascia transversalis, and in its inner part by the conjoint tendon; while the *floor* of the canal is formed by Poupart's ligament, and in its inner part by Gimbernat's ligament. The spermatic cord enters the canal, after piercing the transversalis fascia, at the internal

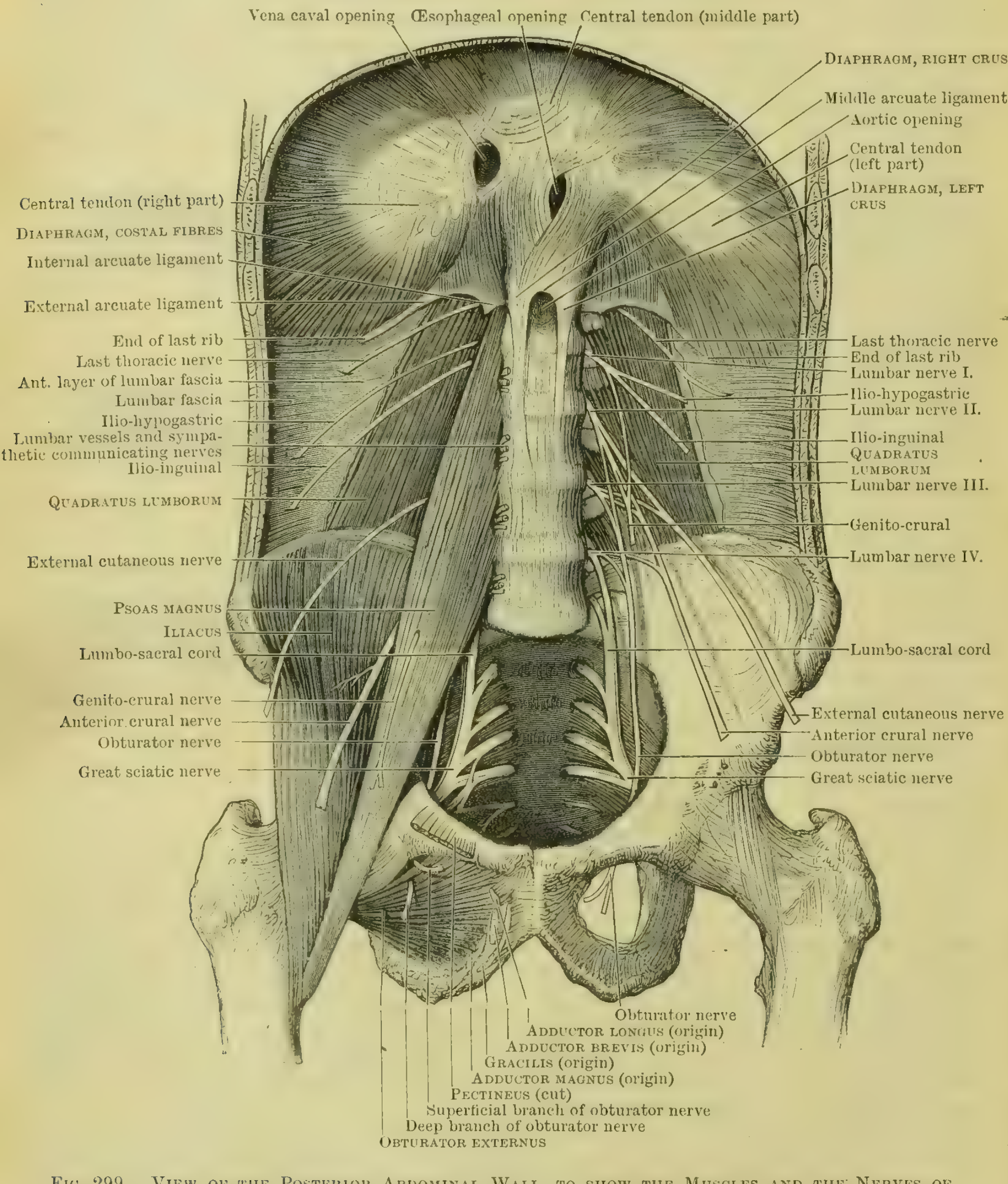


Fig. 299.—View of the Posterior Abdominal Wall, to show the Muscles and the Nerves of the Lumbo-Sacral Plexus.

abdominal ring, and is there invested by its *first envelope*, the **infundibuliform fascia**, derived from the margin of the ring (fascia transversalis). It then passes obliquely inwards, downwards, and forwards, below the lower border of the obliquus internus muscle, from which it carries off a *second investment*, partly fascial, partly muscular —the cremasteric fascia. Continuing its course in front of the conjoint tendon, it emerges through the external abdominal ring, from the edges of which the **intercolumnar fascia** is derived, the *third* or *external investment* for the cord.

Hesselbach's triangle, bounded by the line of Poupart's ligament below, by the rectus muscle internally, and by the deep epigastric artery on the mesial side of the internal abdominal ring externally, is the site of one form of inguinal hernia. The spermatic cord passes over the base of the triangle, covered over by the aponeurosis of the obliquus externus. Behind the cord are the fascia transversalis and the conjoint tendon, which may be said to form the floor of the triangle.

The **posterior muscles of the abdominal wall and false pelvis** include the psoas (magnus and parvus) and iliacus, described already (p. 343), and the quadratus lumborum.

The **quadratus lumborum** lies on the posterior wall of the abdomen external to the psoas, and extends between the iliac crest and the last rib. It **arises** from the posterior part of the iliac crest, from the ilio-lumbar ligament, and from the transverse processes of the lower lumbar vertebræ. It is **inserted** above into the lower border of the last rib and the transverse processes of the upper lumbar vertebræ. It is enclosed between the anterior and middle layers of the lumbar aponeurosis (p. 365), and is placed behind the colon, kidney, and psoas muscle, in front of the multifidus spinæ and the lumbar transverse processes.

Nerve Supply.

The nerve supply of all the foregoing muscles except the psoas, cremaster, quadratus lumborum, and iliacus, is derived from the anterior primary divisions of the **lower six thoracic nerves.** The pyramidalis muscle is innervated by the **last thoracic nerve.** The cremaster muscle receives its supply from the **genito-crural nerve,** whilst the quadratus lumborum is innervated by the first three or four **lumbar nerves.** The psoas and iliacus muscles are supplied, directly or through the **anterior crural nerve,** from the second, third, and fourth lumbar nerves.

Actions.

Many of the actions of the above muscles have already been given in previous sections. (1) Their chief action is to retract the abdominal walls, and, by compressing the contents of the abdomen, they are powerful agents in vomiting, defæcation, micturition, parturition, and laboured expiration. (2) They are also flexors of the spine and pelvis—the muscles of both sides acting together; the spine and pelvis are laterally flexed, when one set of muscles acts alone. (3) The quadratus lumborum is a muscle of inspiration, an extensor of the spine, and a lateral flexor of the spine and pelvis.

FASCIÆ AND MUSCLES OF THE PERINEUM AND PELVIS.

FASCIÆ OF THE PERINEUM.

The **superficial fascia** of the perineum possesses certain special features. It is continuous with the superficial fascia of the abdominal wall, thigh, and buttock, and is prolonged on to the penis and scrotum. In relation to the penis, it is devoid of fat and consists only of areolar tissue. In relation to the scrotum, it is intermingled with involuntary muscular fibres, and constitutes the **dartos muscle,** which assists in suspending the testicles and corrugating the skin of the scrotum. This fascia also forms a **septum for the scrotum,** extending upwards and incompletely separating the two testicles and their coverings. In the female the superficial fascia takes a large share in the formation of the mons veneris and labia majora, in which a considerable quantity of fat occurs.

The fascia over the posterior part of the perineum fills up the ischio-rectal fossæ, in the form of two pads of adipose tissue, on either side of the rectum and anus. Over the tuberosities of the ischium the fat is largely replaced by bands of fibrous tissue closely adherent to the subjacent deep fascia.

The fascia in the anterior part of the perineum closely resembles the same fascia in the groin. It is divisible into a superficial fatty and a deeper membranous layer; the former continuous with the same layer in the thigh, and with the fat of the ischio-rectal fossa posteriorly. The deeper membranous layer is attached laterally to the pubic arch, posteriorly to the base of the triangular ligament, and in the middle line to the root of the penis (bulb and corpus spongiosum) by a

median raphe continuous further forwards with the septum of the scrotum mentioned above. Anteriorly the fascia is continued over the spermatic cords to the anterior abdominal wall. The importance of this fascia lies in relation to the extravasation of urine from a rupture of the urethra. By the fascial attachments the fluid is prevented from passing backwards into the ischio-rectal fossa, or laterally into the thigh. It is directed forwards into relation with the scrotum and penis, and along the spermatic cord to the anterior abdominal wall. The septum of the scrotum being incomplete, fluid extravasated on one side can pass across the middle line to the opposite half of the perineum and scrotum.

The **deep fascia** of the perineum is practically non-existent, except in the form of delicate aponeuroses of the muscles.

THE MUSCLES OF THE PERINEUM.

The perineal muscles are naturally separated into a superficial and a deep set by the triangular ligament. Superficially are the sphincter ani externus, transversus perinei superficialis, bulbo-cavernosus, and ischio-cavernosus; beneath the triangular ligament is the compressor urethræ.

Sphincter ani Externus.—This muscle is fusiform in outline, flattened, and obliquely placed around the anus and anal canal. It can be separated into three

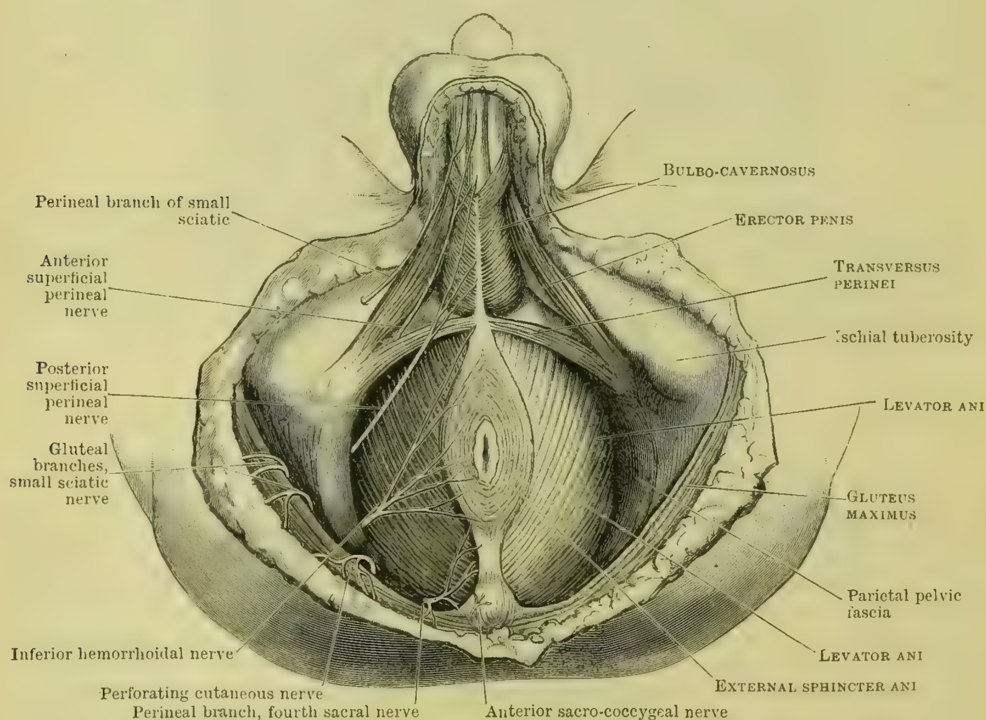


Fig. 300.—The Muscles and Nerves of the Male Perineum.

layers: viz. subcutaneous, superficial, and deep. (1) The most **superficial lamina** consists of subcutaneous fibres decussating behind and in front of the anus, but without bony attachments. (2) The **sphincter ani superficialis** constitutes the main portion of the muscle. It is attached posteriorly to the coccyx, and in front of the anus reaches the central point of the perineum. (3) The **deep fibres** of the muscle form for the most part a complete sphincter for the anal canal. They are continuous with the fibres of the levator ani; they encircle the anal canal, and blend anteriorly with the central point of the perineum and the transversus perinei.

The muscle surrounds the anus, covered only by the skin, superficial fascia, and

the **corrugator cutis ani** (a series of non-striated muscular fibres radiating from the anal opening). It rests on the edge of the levator ani, and forms the median boundary of the ischio-rectal fossa.

The **transversus perinei superficialis** is not always present. It consists of a more or less feeble bundle of fibres, **arising** from the ascending ramus of the ischium and the fascia over it, and from the base of the triangular ligament. It is **inserted** into the central point of the perineum. It conceals the base of the triangular ligament, and has a variable relation to the superficial perineal vessels and nerves.

The **bulbo-cavernosus** (ejaculator urinæ) surrounds the bulb, corpus spongiosum, and root of the penis. It is sometimes separated into two parts—*posterior* (compressor bulbi), and *anterior* (compressor radicis penis). It **arises** from the central point of the perineum, and from a median raphe on the under surface of the bulb and corpus spongiosum. The muscular fibres are directed outwards and forwards, and have a triple **insertion**: from behind forwards, (1) into the under surface of the triangular ligament; (2) into the membrane covering the corpus spongiosum; and, (3) after encircling the corpora cavernosa, into the fascia covering the dorsum of the penis.

The **ischio-bulbosus**, not always present, **arises** from the ischium, and passes obliquely inwards and forwards over the bulbo-cavernosus, to be **inserted** into the raphe superficial to that muscle. It belongs to the same stratum as the transversus perinei and erector penis.

The **compressor hemispherium bulbi** is frequently absent. It consists of a thin cap-like layer of muscular fibres surrounding the extremity of the bulb under cover of the bulbo-cavernosus.

The **bulbo-cavernosus** (sphincter vaginæ) *in the female* is separated into lateral halves by the vaginal and urethral openings. It forms two thin layers covering the vaginal bulbs, and **arises** behind the vaginal orifice from the central point of the perineum. Anteriorly it is **inserted** into the root of the clitoris, some of its fibres embracing the corpora cavernosa so as to reach the dorsum of the clitoris.

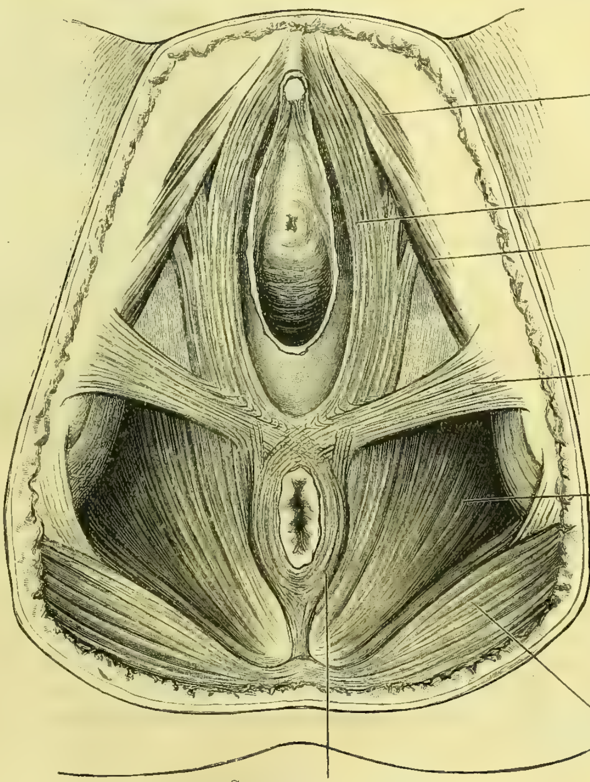


Fig. 301.—The Muscles of the Female Perineum (after Peter Thompson).

The **ischio-cavernosus** (erector penis) covers the crus penis. It **arises** from the ischial tuberosity and the great sacro-sciatic ligament, and passing forwards, is **inserted** by a fascial attachment into the under surface of the crus penis, and into the outer side and dorsal aspect of the corpus cavernosum.

The **ischio-cavernosus** (erector clitoridis) *in the female* has a similar disposition, but is of much smaller size than in the male.

The **pubo-cavernosus** is an occasional slip **arising** from the pubic ramus, and **inserted** into the dorsum of the penis. It corresponds to the levator penis of lower animals.

The **compressor urethræ** (constrictor urethræ) constitutes the deeper muscular stratum of the perineum. It is placed on the pelvic aspect of the triangular ligament. It **arises** from the lower part of the pubic ramus, and is directed inwards, its fibres radiating so as to enclose the membranous urethra. It is **inserted** into a median raphe, partly in front of the urethra, but for the most part behind it. The fibres most intimately related to the urethra form a tubular sheath for the canal, and have no bony attachments.

The most anterior and most posterior fibres of the compressor urethræ exist sometimes as separate muscles.

The **transversus perinei profundus** consists of a bundle of fibres on either side, **arising** from the ascending ramus of the ischium just below the compressor urethræ. It is **inserted** into a median raphe continuous with that of the compressor urethræ. The muscle in fact constitutes a separate bundle below and behind the compressor urethræ.

The **ischio-pubicus** is a term applied to a feeble bundle of fibres which, when present, lies above and in front of the compressor urethræ. It **arises** from the pubic ramus, and is **inserted** into a median raphe in front of the membranous urethra. This muscle is homologous with the **compressor venæ dorsalis penis** of lower animals.

The **compressor urethræ** *in the female* is smaller than in the male. Its insertion is modified by the relations of the urethra to the vagina. The anterior

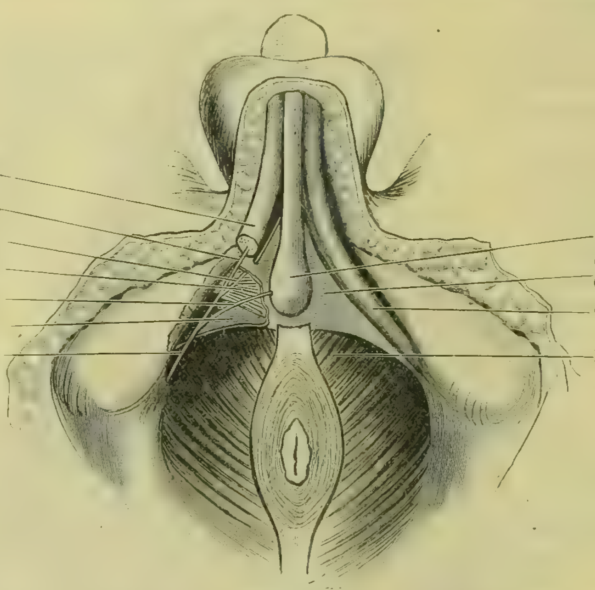


FIG. 302.—THE TRIANGULAR LIGAMENT OF THE PERINEUM, AND THE TERMINATION OF THE PUDIC NERVE.

fibres are continuous with those of the opposite side in front of the urethra; the intermediate fibres pass between the urethra and vagina, and the posterior fibres are attached, along with the **transversus perinei profundus** (transversus vaginæ), into the side of the vagina.

NERVE SUPPLY.

The **pudic nerve** (S. 2. 3. 4.) supplies all the muscles in this group; the external sphincter through the inferior hemorrhoidal, and the others through the perineal branch of the nerve. The external sphincter is also supplied by the perineal branch of the **fourth sacral nerve.**

ACTIONS.

The **external sphincter** closes the anal canal. The **transversus perinei superficialis** draws back and fixes the central point of the perineum, assisted by the external sphincter. The **bulbo-cavernosus** of the male constricts the bulb and corpus spongiosum, and so expresses the last drops

of urine or semen. In the female it acts as a feeble sphincter of the vagina. The **ischio-cavernosus** and **bulbo-cavernosus** help in erection of the penis or clitoris. The **compressor urethræ** constricts the membranous urethra, and in the female helps to flatten and fix the wall of the vagina. It also assists in causing erection of the penis or clitoris by compression of the veins in relation to it.

FASCIA OF THE PELVIS.

The bony pelvic basin, placed obliquely, deeper and more hollowed behind than in front, is to a large extent completed by ligaments (sacro-sciatic ligaments, obturator membrane and triangular ligament). It is almost entirely clothed internally by muscles: by the pyriformis on each side behind, the obturator internus at the side, and the compressor urethræ in contact with the triangular ligament

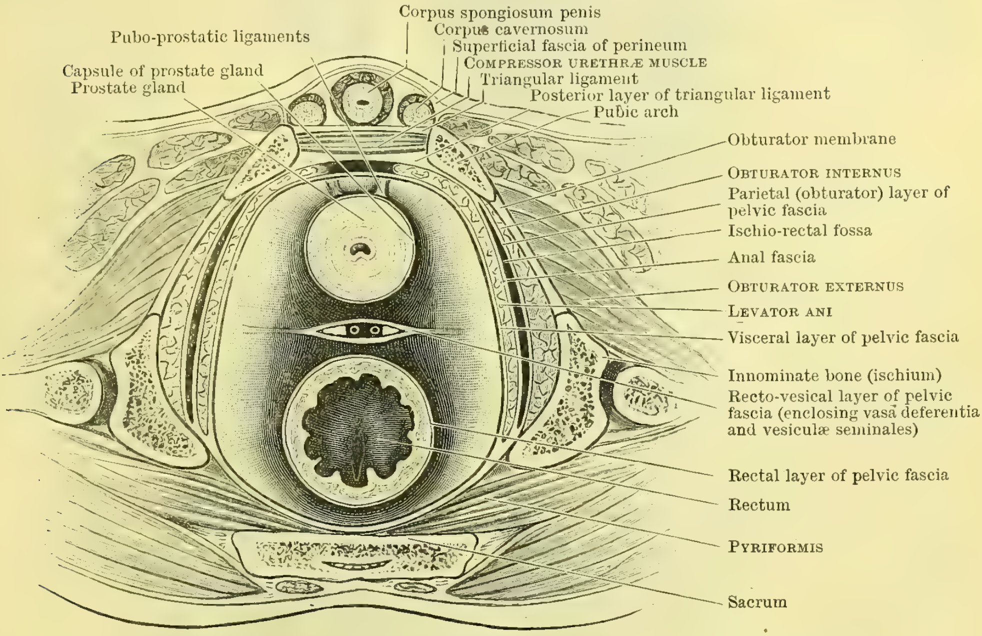


Fig. 303.—Dissection of the Pelvic Fascia from above (diagrammatic).

in front. Indeed, the bones of the pelvis only appear in the cavity in two places; the spine of the ischium projects into the cavity laterally, and the pubis appears in its anterior wall.

The pelvic fascia forms a cylindrical membrane lining the wall of the pelvis, as an aponeurosis for its muscles. It is attached above and below to the inlet and outlet of the pelvis; above to the promontory of the sacrum, ilio-pectineal line, and back of the pubis; below to the coccyx, great sacro-sciatic ligament, tuber ischii, and the base of the triangular ligament. This cylindrical membrane is the **parietal pelvic fascia**; it forms the **pyriformis fascia** behind, the **obturator fascia** at the side of the pelvis, and the so-called **posterior layer** of the **triangular ligament** in front. As this fascia traverses the pelvic wall it obtains attachments to the back of the pubis anteriorly, and to the spine of the ischium on each side. It is deficient in relation to the obturator groove, through which the obturator artery and nerve pass to reach the thigh.

Between the back of the pubis and the spine of the ischium the **white line** extends, a thickened band of the fascia, which roughly indicates the line of separation of the pelvic cavity from the ischio-rectal fossa. The white line serves two purposes: it gives origin to fibres of the levator ani muscle, and from it a secondary sheet of fascia, known as the **visceral pelvic fascia**, arches downwards and inwards across the floor of the pelvis to be connected with the pelvic viscera. This membrane is thin and unimportant behind, as it passes forwards from the lower sacral vertebræ to the rectum. It is thicker at the sides and front of the pelvis,

where it forms a stout membrane concave upwards, continuous mesially with the fibrous coats of the rectum and bladder, and enveloping the prostate gland and vesiculæ seminales. At the front of the pelvis this layer extends from the back of the pubis, to which it is directly attached, to the neck of the bladder and prostate gland, and gives rise to two folds — the **pubo-prostatic ligaments**, enclosing a hollow between them,— the **cavum Retzii.** The lateral portion of the visceral pelvic fascia constitutes the **recto-vesical layer,** divisible into three parts —*vesical, rectal,* and between these the *recto-vesical layer,* a partition insinuated between the rectum and bladder, and enclosing the vesiculæ seminales and vasa deferentia. This visceral pelvic fascia thus forms a support for the pelvic viscera, and at the same time acts as a partition between the pelvic cavity and the perineum. It is separated from the pelvic cavity by the peritoneum and the extra-peritoneal tissue, and is in contact with the levator ani on its perineal surface. The internal iliac vessels and their branches lie on the pelvic aspect of the fascia, and the parietal vessels pierce and are ensheathed by it as they leave the pelvis. On the other hand the spinal nerves (sacral plexus) lie outside the fascia, with one exception. The obturator nerve and artery leave the pelvis through a special hole in the pelvic wall, after traversing the extra-peritoneal tissue.

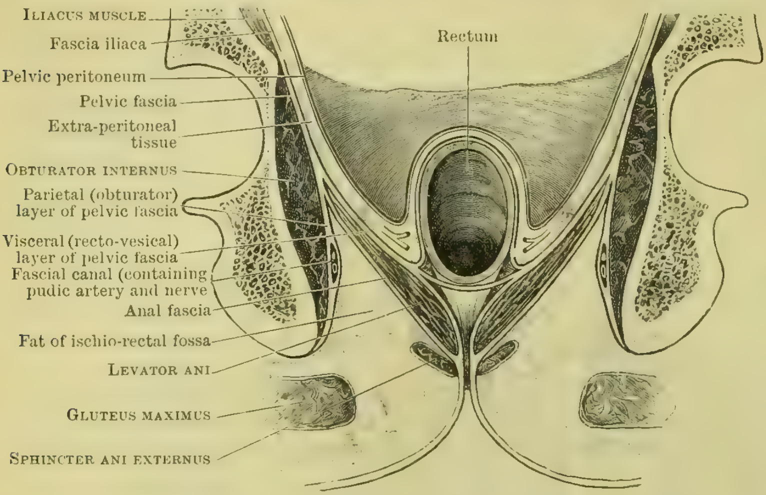


FIG. 304.—OBLIQUE SECTION ACROSS THE PELVIS, TO SHOW THE DISPOSITION OF THE PELVIC FASCIA AND THE BOUNDARIES OF THE ISCHIO-RECTAL FOSSA.

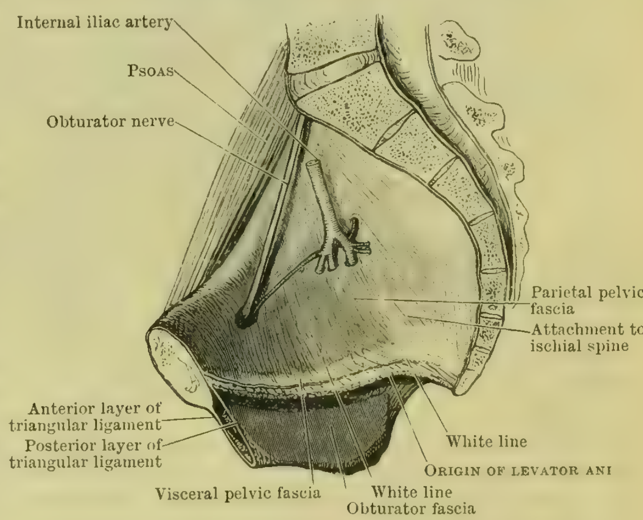


FIG. 305.—THE OUTER WALL OF THE PELVIS (pelvic fascia).

The *pelvic fascia in the female* only differs in slight detail from that of the male. It encloses the neck of the bladder and vagina instead of the prostate gland, and invests the lower part of the neck of the uterus instead of the vesiculæ seminales.

MUSCLES OF THE PELVIS.

The pelvic diaphragm consists of several more or less rudimentary muscular slips, constituting the levator ani and ischio-coccygeus muscles, which serve to uphold the pelvic floor, and are related to the rectum and the prostate gland or vagina.

The **levator ani arises** from (1) the back of the body of the pubis, (2) the parietal pelvic fascia above or along the *white line,* and (3) the spine of the ischium. Its fibres are directed downwards and backwards, to be **inserted** into (1) the central point of the perineum, (2) the external sphincter around the anus and the ano-coccygeal raphe behind the anus, and (3) into the sides of the lower sacral and the coccygeal vertebræ.

The concave upper surface of the muscle is covered in part by the visceral

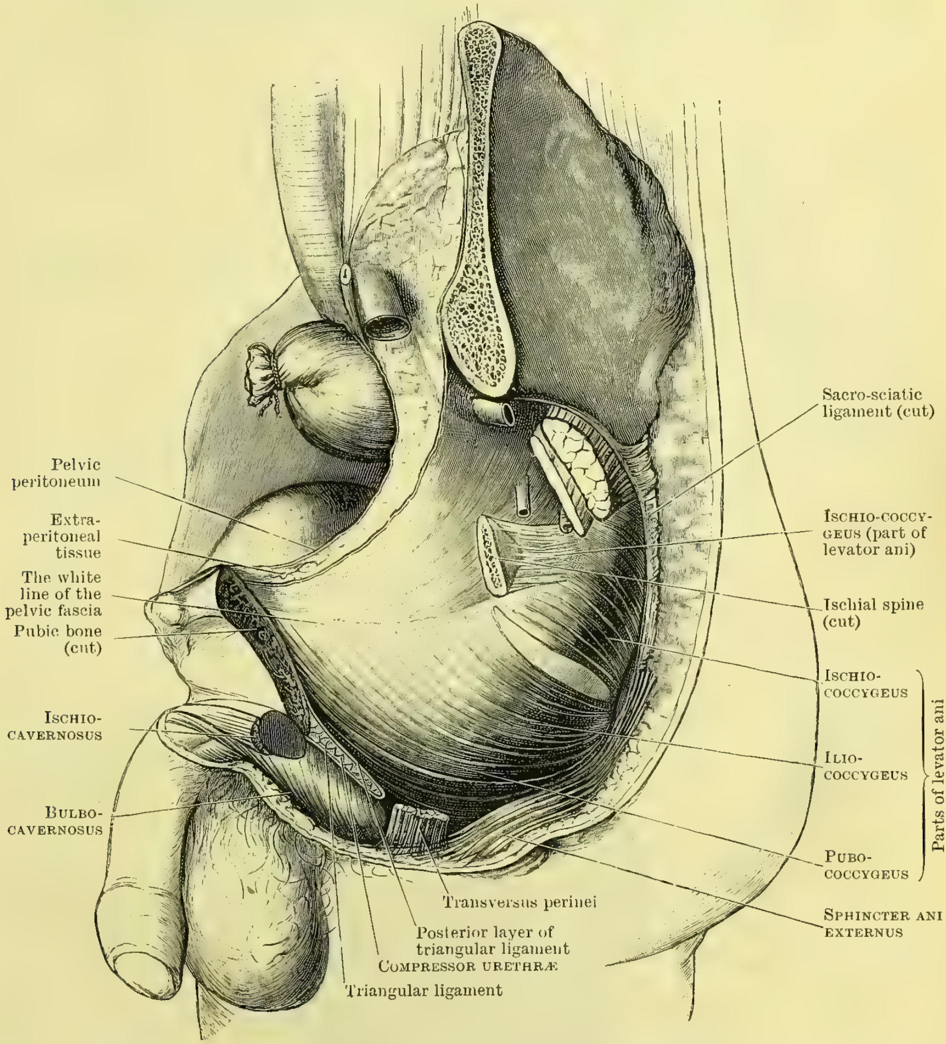


FIG. 306.—THE FASCIAL AND MUSCULAR WALL OF THE PELVIS AFTER REMOVAL OF PART OF THE LEFT INNOMINATE BONE.

pelvic fascia; in part it is in contact with the rectum behind and the prostate gland or vagina in front. The inferior convex surface of the muscle forms the inner wall of the ischio-rectal fossa. Its posterior edge is overlapped by the ischio-coccygeus; its anterior edge is in contact with the posterior layer of the triangular ligament.

The **levator ani** is divisible into four parts—pubo-rectalis, pubo-coccygeus, ilio-coccygeus, and ilio-sacralis. The **pubo-rectalis** (levator prostatæ) is the part inserted into the central point of the perineum. The **pubo-coccygeus** is the part inserted into the anus and the ano-coccygeal raphe, and the **ilio-coccygeus** and **ilio-sacralis** are represented by the fibres attached to the sacrum and coccyx. The first two are best developed; the last two series of fibres the most rudimentary. These several parts of the muscle represent the remains of the flexor caudæ of tailed animals.

The **ischio-coccygeus** is a rudimentary muscle overlapping the posterior border of the levator ani. It **arises** from the ischial spine and the small sacro-sciatic ligament, and is **inserted** into the sides of the lower two sacral and upper two coccygeal vertebræ. The muscle is separated from the rectum by the visceral pelvic fascia, and is in contact externally with the sacro-sciatic ligaments.

Nerve Supply.

The **levator ani** is supplied by two nerves: by the perineal (muscular) branches of the pudic nerve, and, on its pelvic surface, by special branches from the third and fourth sacral nerves. The **ischio-coccygeus** is supplied on its pelvic surface by the third and fourth sacral nerves.

Actions.

(1) The levator ani and ischio-coccygeus serve to uphold and slightly raise the pelvic floor. (2) They are likewise capable of producing slight flexion of the coccyx. (3) The anterior fibres of the levator ani, in the female, sweeping round the vagina, compress its walls laterally, and along with the sphincter vaginæ, help to voluntarily diminish the lumen of the tube. (4) The same part of the muscle in the male elevates the prostate gland (levator prostatæ). (5) The chief action of the levator ani is in *defæcation.* Along with the external sphincter it acts as a sphincter of the rectum, closing the anal canal. During defæcation the muscle draws upwards the anus over the fæcal mass, and so assists in its expulsion. (6) *In parturition*, in the same way, the muscle, contracting below the descending fœtal head, retards delivery. Contracting on the fœtal head, it draws upwards the pelvic floor over the fœtus, and so assists delivery.

THE DEVELOPMENT AND MORPHOLOGY OF THE SKELETAL MUSCLES.

Our knowledge of the development and morphology of the muscular system is very incomplete. It has already been shown, in the chapter on general embryology, that the

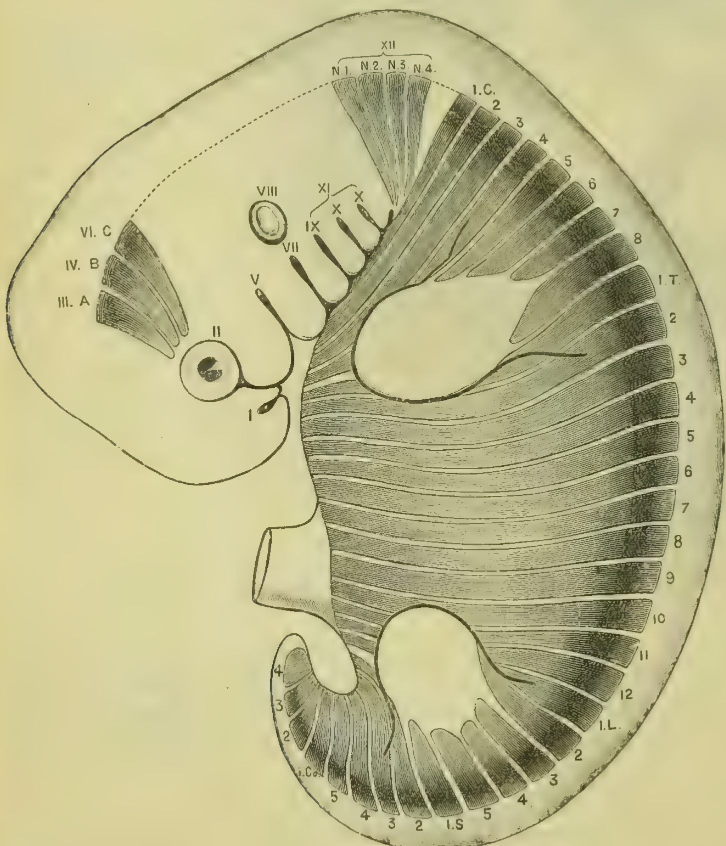


Fig. 307.

Scheme to Illustrate the Disposition of the Myotomes in the Embryo in Relation to the Head, Trunk, and Limbs.

A, B, C, First three cephalic myotomes; N, 1, 2, 3, 4, Last persisting cephalic myotomes; C., T., L., S., Co., The myotomes of the cervical, thoracic, lumbar, sacral, and caudal regions; I., II., III., IV., V., VI., VII., VIII., IX., X., XI., XII., refer to the cranial nerves and the structures with which they may be embryologically associated.

mesoblast on either side of the embryonic medullary tube separates into three main parts—the **myotome, nephrotome**, and **lateral plates** (somatopleure and splanchnopleure).

The **myotomes** are probably directly or indirectly the source of the striated muscles of the whole body. Each consists at first of a quadrilateral bilaminar mass, resting

against the medullary tube and notochord on either side. The cleft between its two layers represents the remains of the cœlomic cavity. In young embryos it is to be seen in an active condition of growth. On its inner side masses of cells arise, which grow inwards and surround the medullary tube and notochord to form the foundation of the vertebral column. On its outer side cells appear to be given off which participate in the formation of the cutis vera. At the same time the dorsal and ventral borders of the myotome continue to extend, and present extremities (growing points) with an epithelial structure for a considerable period. *On the dorsal side* it overlies the medullary tube, and gives rise to the muscles of the back; while by its *ventral extension*, which traverses the somatopleuric mesoblast in the body wall, it produces the lateral and ventral muscles of the trunk. By an inward extension it probably gives rise also to the hypaxial muscles of the neck and loin. The cells of the inner layer of the myotome are responsible for the formation of the muscle fibres. Elongating in a direction parallel to the long axis of the embryo, they give rise by fusion with the cells of neighbouring myotomes to the columns and sheets of muscles of the back and trunk. For the most part (*e.g.* back and abdomen) the originally segmental character of the muscular elements is lost by the more or less complete fusion of adjacent myotomes. The intercostal muscles, however, are the direct derivatives of individual myotomes.

Muscles of the Limbs.—In fishes (elasmobranchs) and reptiles there is evidence that the myotomes are concerned in the formation of the limb-muscles by the extension of the myotomes into the limb-bud in a manner similar to that described for the trunk. In birds and mammals, however, in which the limb-bud arises as an undifferentiated, unsegmented mass of mesoblastic tissue, partly from the mesoblast surrounding the notochord, and partly from the somatopleuric mesoblast, the myotomes stop short at the root of each limb, and do not penetrate into its substance. Instead, the muscular elements of the limb take origin independently as *double dorsal* and *ventral strata* of fusiform cells on the dorsal and ventral surfaces of the axial cartilages of the limb. These strata are *unsegmented;* they are grouped around the skeletal elements of the limb, and they gradually become differentiated into the muscle masses and individual muscles of the limb.

Muscles of the Head.—Notwithstanding the obscurity and complexity of this subject, it appears certain that *at least two series* of elementary structures are concerned in the formation of the muscles of the head and face—the **cephalic myotomes** and the muscular structure of the **branchial arches.**

The number of myotomes originally existing in the region of the head is not known, although it is stated with some authority that nine were primitively present. The *first three* are described as persisting in the form of the ocular muscles, the *last three* in relation to the muscles of the tongue, while the *three intervening myotomes* disappear.

The following table shows the probable fate of the cephalic myotomes :—

First, Superior, internal and inferior recti, obliquus inferior, levator palpebræ superioris.
Second, Obliquus superior.
Third, Rectus externus.
Fourth, *Fifth* and *Sixth*, Absent.
Seventh, *Eighth*, } Muscles of the tongue.
Ninth, *Tenth* (*or first cervical*) } Muscles connecting cranium and shoulder-girdle.

The **mesoblastic tissue of the branchial arches** is probably concerned in the production of the following muscles of the face and neck :—

First (mandibular) arch . .	Muscles of mastication.
Second (hyoid) arch . . .	Platysma myoides and facial muscles. Muscles of soft palate. Stapedius, stylo-hyoid, and digastric.
Third (thyro-hyoid) arch . .	Stylo-pharyngeus. Superior constrictor.
Fourth and Fifth (branchial) arches	Middle and inferior constrictors. Muscles of larynx.

THE NERVOUS SYSTEM.

THE BRAIN AND SPINAL CORD, WITH THEIR MENINGES.

By D. J. Cunningham.

The nervous system connects the various parts of the body with each other and co-ordinates them into one harmonious whole. Its relatively great bulk and its extreme complexity constitute two of the most distinctive structural features of man. It consists of two parts, viz. the cerebrospinal nervous system and the sympathetic nervous system.

The **sympathetic nervous system** is composed of a chain of serially disposed ganglia, bound to each other by intervening nervous cords, and placed one on either side of the vertebral column. In addition to these gangliated cords, the sympathetic system includes certain dense plexuses of nerves and numerous scattered ganglia. The whole is most intimately connected with the cerebrospinal nervous system, and both have apparently a common developmental origin. The separation of the nervous system into the two leading subdivisions of sympathetic and cerebrospinal is therefore of a somewhat arbitrary kind.

The **cerebrospinal nervous system** consists of the brain, which very nearly completely fills the cranial cavity, and the spinal cord or spinal marrow, which only partially fills the vertebral canal. These are continuous with each other, and together constitute the cerebrospinal axis. Attached to the brain and spinal cord are the numerous nerves which bring the various parts of the body into connexion with the central nervous axis. There are thirty-one pairs of symmetrically disposed **spinal nerves** attached to each side of the spinal cord. Each of these nerves is connected to the side of the cord by a **ventral** or **anterior** and a **dorsal** or **posterior root**, and the dorsal root is distinguished by presenting a distinct oval swelling, termed a **spinal ganglion**, on that part of its course immediately internal to the place where the two roots unite to form the **spinal nerve-trunk** (Fig. 316, p. 422).

The **cranial nerves** are twelve in number, but one only (viz. the fifth or trigeminal) presents a double-rooted attachment similar to a spinal nerve. Several, however, possess ganglia in every respect comparable with the ganglia on the dorsal roots of the spinal nerves. These are the fifth or trigeminal, the seventh or facial, the eighth or auditory, the ninth or glosso-pharyngeal, and the tenth or vagus cranial nerves.

CEREBROSPINAL NERVOUS SYSTEM.

The brain and spinal cord are composed of two substances which present a different appearance to the eye, and which, consequently, are distinguished by the terms **white matter** and **gray matter**. The difference in colour between these two substances depends not only upon the different elements which enter into their formation, but also upon the fact that the gray matter is the more vascular of the two. The white matter is chiefly composed of nerve-fibres, whilst the essential constituents of the gray matter are nerve-cells which give origin to nerve-fibres. The elements which constitute nervous tissue are nerve-cells, nerve-fibres, and neuroglia.

Nerve-fibres.—Nerve-fibres arranged in bundles of greater or less bulk form

the nerves which pervade every part of the body. They also constitute the greater part of the brain and spinal cord. Nerve-fibres are the conducting elements of the nervous system which serve to bring the nerve-cells into relation both with each other and with the various tissues of the body.

There are different varieties of nerve-fibres, but in all the leading and essential constituent is a delicate thread-like band, termed the **axis cylinder.** The difference between individual fibres depends upon the fact that in some cases the axis cylinder becomes invested by one or two coats, whilst in other cases it remains naked. When the axis cylinder is coated on the outside by a more or less thick sheath of a fatty substance termed **myelin,** it is said to be a myelinated or medullated fibre. When the coating of myelin is absent, the fibre is termed a non-myelinated or a non-medullated fibre. A second sheath—thin, delicate, and membranous, and placed externally—may also be present in both cases. It is termed the **primitive sheath** or the **neurolemma.** From a structural point of view, therefore, four different forms of nerve-fibre may be recognised:—

non-medullated { 1. Naked axis cylinders.
2. Axis cylinders with primitive sheaths.

medullated { 3. Primitive sheath absent.
4. Primitive sheath present.

Every nerve-fibre near its origin and as it approaches its termination is unprovided with sheaths of any kind, and is simply represented by a non-medullated naked axis cylinder. The fibres of the olfactory nerves afford us an example of non-medullated fibres furnished with a primitive sheath.

Medullated fibres are present in greater quantity in the cerebrospinal system than non-medullated fibres. Thus all the nerves attached to the brain and cord, with the exception of the olfactory and optic, are formed of medullated fibres provided with a primitive sheath; whilst the entire mass of the white substance of the brain and cord, and also the optic nerves, are formed of medullated fibres devoid of a primitive sheath.

It is important to note that the distinction between the medullated and non-medullated fibres is not one which exists throughout all stages of development. As will be presently pointed out, every fibre is a direct outgrowth from a cell, and in the first instance none are provided with a medullary sheath. Indeed, it is not until about the fifth month of fœtal life that those fibres which are to form the white substance of the cerebrospinal axis begin to acquire their coating of myelin. Further, this coating appears in the fibres of different strands or tracts at different periods, and a knowledge of this fact has enabled the anatomist to follow out the connexions of the tracts of fibres which compose the white matter of the brain and cord.

FIG. 308.
NERVE-FIBRE FROM A FROG (after v. Kölliker.)

But it may be asked: How does a nerve-fibre arise and how does it end? Every fibre is directly continuous by one extremity with a nerve-cell, whilst its opposite extremity breaks up into a number of ramifications, all of which end freely in relation to another nerve-cell, or in relation to certain tissues of the body, as, for example, to muscle-fibres or to the epithelial cells of the epidermis. The length of nerve-fibres, therefore, varies very greatly. Some fibres are so short as merely to bring two neighbouring nerve-cells into relation with each other: others travel long distances. Thus a fibre arising from one of the motor cells of the lower end of the spinal cord may, after leaving the cord, extend to the most outlying muscle in the sole of the foot before it reaches its destination. But even when a fibre does not leave the central axis a great length may be attained, and cells situated in the motor area of the cortex of the cerebrum may give origin to fibres which pass down to the lower end of the cord.

Physiologists classify the fibres which form the nerves into two sets, afferent and efferent. **Afferent nerve-fibres** conduct the impulse of impressions from the

peripheral organs into the central nervous system; and as a change of consciousness, or, in other words, a sensation is a frequent result, these fibres are often called *sensory*. **Efferent fibres** carry impulses out from the brain and cord to peripheral organs. The majority of these fibres go to muscles and are termed *motor;* others, however, go to glands and are called *secretory;* whilst some are *inhibitory* and serve to carry impulses which restrain or check movement or secretion. As previously stated, the spinal nerves are each attached to the cord by a ventral or anterior root, and a dorsal or posterior root; the fibres composing the former are efferent; whilst the fibres of the posterior root are almost entirely afferent.

Nerve-cells.—The nerve-cells constitute the active and all-essential elements of nerve-tissue. At the very start it is necessary to draw a broad distinction between the ganglionic cells, which are found in the spinal ganglia, and the cells which are so plentifully scattered through the gray matter of the brain and cord. They differ not only in their mode of origin and in their subsequent development, but also in the connexions of the nerve-fibres to which they give origin.

Nerve-cells of the Brain and Cord.—The cells in the gray matter of the cerebrospinal axis are variable both in size and form. Some are relatively large, as, for example, certain of the pyramidal cells of the cerebral cortex and the motor cells in the gray matter of the cord, which almost come within the range of unaided vision; others are exceedingly minute, and require a high power of the microscope to bring them into view. The cell consists of a protoplasmic nucleated body, from which certain processes proceed. One process is termed the **axis-cylinder process** or **axon**; and as a rule it is easily distinguished from the others, which are collectively called the **protoplasmic processes of Deiters**, or the **dendrites.**

The **axon** presents a uniform diameter and a smooth and even outline. It gives off in its course fine collateral branches, but does not suffer thereby any marked diminution in its girth. The most important point to note in connexion with the axon, however, is the fact that it becomes continuous with the axis-cylinder of a nerve-fibre. The significance of this is obvious, and will become more striking when the development of the nerve-cells is studied. The axon then is simply a nerve-fibre, and in certain circumstances it assumes, as already stated, one or two investing sheaths. The axon may run its entire course within the substance of the brain or cord either for a short or a long distance, or it may emerge from the brain or cord in one of the cranial or spinal nerves as the essential part of an efferent nerve-fibre and run a variable distance before it finally reaches the peripheral structure in relation to which it ends. The axon and the collaterals which spring from it terminate either in small button-like swellings or knobs, or more frequently in terminal arborisations, the extremities of which are free and are furnished with exceedingly small terminal varicosities. In those cases where the axon or its collaterals end within the brain or cord, some of the terminal arborisations interlace with the dendrites of nerve-cells, whilst others are twined around the bodies of other cells. In the latter case the interlacement may be so close and complete that it almost presents the appearance of an enclosing basket-work. In cases where the axon emerges from the cerebrospinal axis its terminal arborisation ends in relation to a muscle-fibre or some other tissue in the manner already referred to. In all cases, however, it must be clearly understood that the terminal branches of the axon, no matter how complicated the connexion may appear, are free, and that the connexion is simply one of contact or contiguity, and not one of continuity.

Held maintains that, although at first the terminal arborisations of an axon are quite free, in the process of growth and development they exhibit a tendency to become fused with the dendrites and even the bodies of other nerve-cells.

The **dendrites**, or protoplasmic processes of the nerve-cell, are thicker than the axon, and present a rough-edged irregular contour. They divide into numerous branches, and these gradually, as they pass from the cell-body, become more and more attenuated until they finally end in free extremities. The branching of the dendritic processes sometimes attains a marvellous degree of complexity, but it is now satisfactorily established that, except in exceptional circumstances, there is no

anastomosis between the dendrites of neighbouring cells, or between the dendrites of the same cell. It would appear, therefore, that nothing in the shape of a network is formed by these processes.

In the chapter upon Embryology it has been shown that in the early condition of the cerebrospinal axis the brain and cord consist simply of a thin-walled tube (p. 20). The wall of this tube is formed of a single layer of tall columnar neuro-epithelial cells, and in its deepest or most internal part large round cells make their appearance in the intervals between the epithelial columns. These new cells are termed the **germinal cells**, and from them the nerve-cells are derived. They are

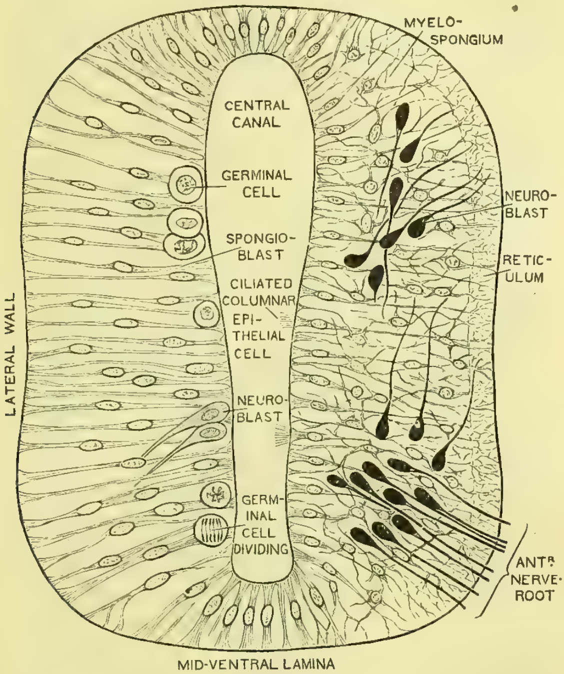


FIG. 309.—TRANSVERSE SECTION THROUGH THE EARLY NEURAL TUBE, diagrammatically represented (Alfred H. Young).
The left side of the section exhibits an earlier stage of development than the right side.

FIG. 310.—THE DEVELOPMENTAL STAGES EXHIBITED BY A PYRAMIDAL CELL OF THE BRAIN (after Ramón y Cajal).

a, Neuroblast with rudimentary axon, but no dendrites ; *b* and *c*, The dendrites beginning to sprout out ; *d* and *e*, Further development of the dendrites and appearance of collateral branches on the axon.

present in considerable numbers, and towards the fourth week of embryonic life they form an almost continuous layer. Although these cells ultimately become nerve-cells they are absolutely without processes in their early state, and therefore at this period, although there is a nervous system, there are, as His remarks, no nerves. In course of time, and as the wall of the neural tube thickens, the germinal cells begin to migrate in an outward direction. They leave the deep part of the wall of the neural tube and proceed to take up the positions they occupy in the gray matter of the cord and brain of the adult. These migrating cells assume a pyriform shape, and are termed **neuroblasts.** The drawn-out portion or stalk of the pear-shaped neuroblast represents the early axon, and this continues to grow and increase in length until it ultimately attains the terminal relations characteristic of the adult. The study of embryology presents few more remarkable phenomena than the manner in which this axon grows out, and, in the efferent nerve-fibres, emerges from the central axis, and yet pursues its allotted path with the most unerring exactitude and precision until it ultimately reaches the nerve-cell or the peripheral tissue element with which it becomes associated. The growing point of both it and its collaterals is slightly bulbous, and it is out of this that the terminal arborisation is formed.

The dendritic processes of the nerve-cell appear at a later period than the axon. The surface of the neuroblast becomes rough and then somewhat spiny. By the growth and subdivision of these spiny projections the dendrites are formed. As

His remarks, the nerve-cell is therefore the genetic centre from which all the parts of a nervous element proceed.

It must now be clear that each nerve-cell is a unit which is separate and distinct from the nerve-cells which lie around it. Further, it is obvious that it is wrong to consider the nerve-cell as something apart from the nerve-fibre. The nerve-cell with its dendrites and axon, however wide-spreading these processes may be, constitutes an independent system to which the term **neuron** is applied, and the only relation which it has with other neurons or with peripheral tissues is one of contact.

Ganglionic Nerve-Cells.—The ganglionic neurons found in the ganglia of the cranial nerves and in the ganglia on the dorsal roots of the spinal nerves have a different origin, and present many points of contrast with neurons in the gray matter of the brain and cord. As already indicated in the chapter on Embryology (p. 20) the ganglia in question are derived from the neural crest. The cells forming these ganglionic masses are somewhat oval in form, and from either extremity or pole a process grows out, and the neurons in this manner become bipolar. These processes are distinguished as central and peripheral, according to the direction which they take. The central processes grow inwards, and penetrate the wall of the neural tube. In the region of the spinal cord they form almost the whole of the fibres which enter into the composition of the dorsal roots of the spinal nerves. In the substance of the cerebrospinal axis they give off numerous collaterals, and after a course of varying extent they end, after the manner of an axon, in terminal arborisations, which enter into relationships of contact with certain nerve-cells in the cerebrospinal axis. The peripheral processes grow outwards along the path of the particular nerve with which they are associated, and they finally establish peripheral contact relations. Thus, to take one example: the majority of the fibres which go to the skin break up into fine terminal filaments, which end freely between the epithelial cells of the epidermis. The two processes of a ganglion cell, therefore, form the afferent fibres of the cerebrospinal nerves, and constitute the path along which the influence of peripheral impressions is conducted towards the brain and cord. The body of the cell is as it were interposed in the path of such impulses.

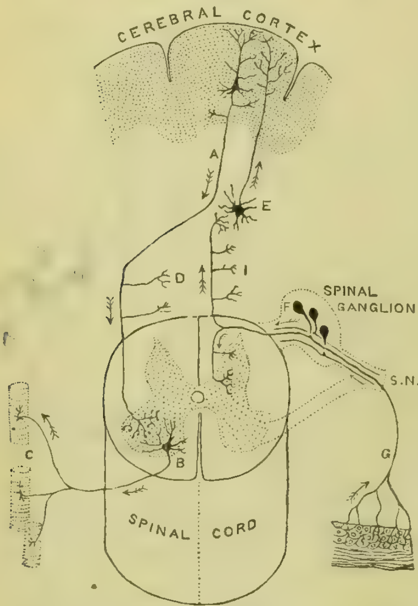


FIG. 311.—DIAGRAM OF THE CONNEXION ESTABLISHED BY A GANGLIONIC AND A MOTOR NEURON (Ramón y Cajal).

A. Fibre coming down from a pyramidal cell in the motor area of the cerebral cortex.
B. Motor cell in gray matter of spinal cord.
C. Muscle-fibres.
D. Collateral branch from the pyramidal fibre.
E. Cell in the medulla oblongata sending its axon upwards to the cerebral cortex.
F. Cells in spinal ganglion.
G. Peripheral process of ganglionic cell ending in skin.
I. Collateral branches of central process of ganglionic cell.
S.N. Spinal nerve.

But the original bipolar character of these cells, with very few exceptions (ganglia in connexion with the auditory nerve and the bipolar nerve-cells in the olfactory mucous membrane), gradually undergoes a change which ultimately leads to their transformation into unipolar cells. This is brought about by the tendency which the cell-body has to grow to one side, viz. the side towards the surface of the ganglion (v. Lenhossek). This unilateral growth leads to a gradual approximation of the attached ends of the processes, and finally to a condition in which they appear to arise from the extremity of a short common stalk in a T-shaped manner (Fig. 312). It is interesting to note that the original bipolar condition of these cells is retained throughout life without change in certain fish.

Both the central and peripheral processes of these ganglionic cells become the axis cylinders of nerve-fibres, which, acquiring a medullary sheath, belong therefore to the medullated variety. From this it might very naturally be thought that the

ganglionic neuron, with its two axons and no typical dendrites, is a nervous unit very different from a neuron in the gray matter of the cerebrospinal axis. It is believed by some, however (van Gehuchten and Cajal), that the peripheral process, in spite of its enclosure within a medullary sheath, and though presenting all the characters of a true axon, is in reality a dendrite. If this be the case, the morphological difference between a dendrite and an axon disappears, and van Gehuchten's functional distinction alone remains characteristic, viz. that the axon is *cellulifugal* and conducts impulses away from the cell, whilst the dendrites are *cellulipetal* and conduct impulses towards the cell.

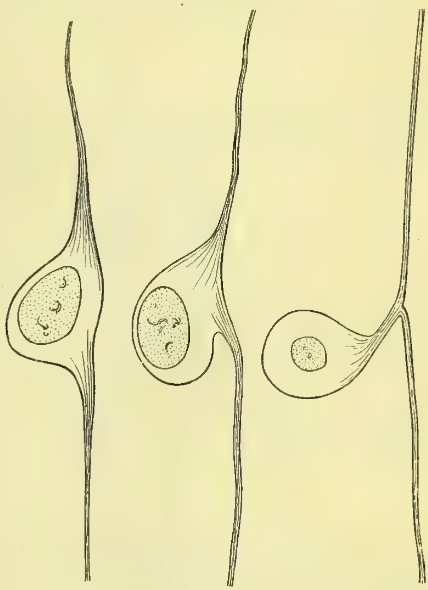


Fig. 312.—Three Stages in the Development of a Cell from a Spinal Ganglion.

Neuroglia.—The neuroglia is the supporting tissue of the cerebrospinal axis. It may be considered to include two different forms of cells, viz. the lining ependymal cells and the neuroglia cells proper. We place these cells under the one heading, seeing that in all probability they both have a common developmental origin.

The **ependymal cells** are the columnar epithelial cells which line the central canal of the spinal cord and the ventricles of the brain. In the embryonic condition a process from the deep extremity of each cell traverses the entire thickness of the neural wall and reaches the surface. It is not known whether this process exists in the adult.

The **neuroglia cells proper** are found in great numbers scattered throughout the gray and white substance of the brain and cord. They present many different forms, but the leading and distinguishing feature consists in the great number of fine branching processes which as a rule pass out from all parts of the body. These neuroglial cells act as a sort of packing material placed between the nervous elements, and their processes twine around the different parts of the neurons in such a way as both to isolate them and bind them together.

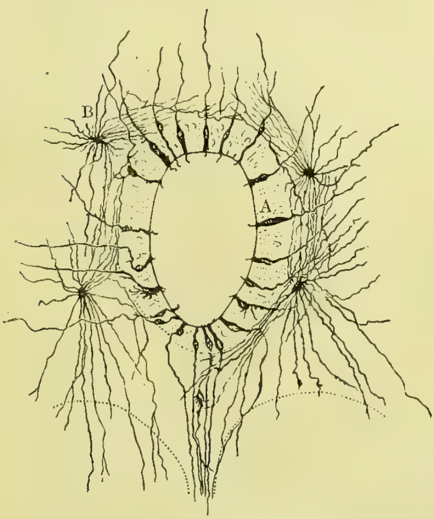


Fig. 313.—Section through the Central Canal of the Spinal Cord of a Human Embryo, showing Ependymal and Neuroglial Cells (after v. Lenhossek).
A, Ependymal cell. B, Neuroglial cell.

The ependymal cells are undoubtedly derived from the original neuro-epithelial cells of the early neural tube, and in all probability the neuroglia cells proper have a similar origin. They both, therefore, proceed from the ectoderm.

Summary.—1. The cerebrospinal nervous system is composed of two parts, viz. (*a*) a **medullary part**, consisting of the brain and spinal cord, with the efferent nerve-fibres which pass out from them; (*b*) the **ganglionic part**, with the afferent nerve-fibres.

2. Each of these parts has a different origin and is composed of neurons which possess characteristic features.

3. The ganglionic neurons are derived from the primitive cells of the neural crest, and have each one process which divides into two. Of these the central division enters the cerebrospinal axis and probably represents the axon, whilst the

peripheral division, which becomes connected with a peripheral part, may provisionally be regarded as a dendrite. The central fibres from the ganglionic cells in the region of the cord form the dorsal or posterior roots of the spinal nerves. These roots have thus an origin outside the cord, and grow into its substance in the process of development in the same manner that the roots of a plant strike into the soil.

4. The cerebrospinal neurons are derived from the germinal cells in the wall of the early neural tube. Certain of these furnish efferent nerve-fibres, which issue from the cord in separate bundles termed the anterior or ventral roots of the spinal nerves. In the case of the cranial nerves, however, with the exception of the trigeminal and facial nerves, the efferent fibres are not thus separated from the afferent fibres at their attachment to the brain.

5. The brain and cord when studied by the naked eye are seen to be composed of white matter and gray matter. The white matter forms very nearly two-thirds of the entire cerebrospinal axis. It is composed of medullated nerve-fibres embedded in neuroglial tissue. The gray matter is composed of nerve-cells with their dendrites and axons. Some of the axons are in the form of naked axis cylinders, whilst others have a coating of medulla. Intimately intermixed with these parts is the neuroglia, which isolates them more or less completely from each other.

SPINAL CORD.

The **spinal cord** is that part of the cerebrospinal axis which occupies the upper two-thirds of the spinal canal of the vertebral column. It is an elongated cylindrical structure, slightly flattened in front and behind, which extends from the margin of the foramen magnum to the level of the lower border of the body of the first lumbar vertebra or to the upper border of the body of the second lumbar vertebra. Its average length in the male is 45 cm. and in the female 43 cm.

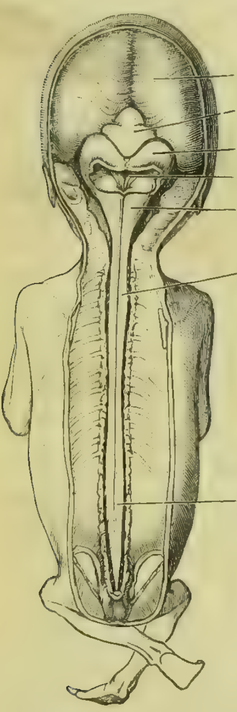


Fig. 314.—Human Fœtus in the third month of development, with the Brain and Spinal Cord exposed from behind.

A considerable amount of variation within certain limits (viz. the mid-point of the body of the last dorsal vertebra and the upper border of the body of the third lumbar vertebra) is observed in different individuals as to the precise level at which the spinal cord ends inferiorly, and in the female there would appear to be a tendency for the cord to reach a slightly lower point in the canal than in the male. Further the relation presented by the spinal cord to the vertebral column differs in a marked degree in the fœtus and infant at different periods of development. Up to the third month of intrauterine life the cord occupies the entire length of the spinal canal; it extends downwards to the lowest limit of the canal. But from this time on, as growth proceeds, the vertebral column lengthens at a more rapid rate than the cord. The spinal cord, therefore, has the appearance of shrinking in an upward direction within its canal, and at birth its lower end is usually found to be opposite the body of the third lumbar vertebra.

The attitude assumed by the individual affects to a small degree the position of the lower end of the cord. Thus, when the trunk is bent well forwards, it is noticed that the terminal part of the cord rises slightly within its bony canal.

At the margin of the foramen magnum the spinal cord becomes continuous with the medulla oblongata of the brain, whilst below, it tapers rapidly to a point and forms a tapering extremity termed the **conus medullaris.** From the end of the conus medullaris a slender glistening thread is prolonged downwards within the spinal canal, and finally anchors the spinal cord to the back

of the coccyx. This prolongation receives the name of the **filum terminale**. The diameter of the cord is very much shorter than that of the spinal canal within which it lies. A wide interval is left between its surface and the walls of its canal, and this excess of space is clearly a provision for allowing free movement of the vertebral column without producing any jarring contact between the delicate spinal cord and the surrounding bones.

Three protective membranes are wrapped around the cord. From within outwards these are termed (1) the pia mater; (2) the arachnoid mater, and (3) the dura mater. The **pia mater** is a fibrous membrane which forms the immediate investment. It is closely applied to the cord, and from its deep surface numerous fine septa penetrate into the substance of the cord. The **arachnoid mater** is an exceedingly delicate transparent membrane which is loosely wrapped around the cord so as to leave a considerable interval, termed the subarachnoid space, between itself and the pia mater, in which there is always a varying amount of cerebrospinal fluid. Outside the arachnoid mater, the **dura mater** forms a wide, dense, fibrous, tubular sheath, which extends downwards within the spinal canal for a considerable distance beyond the conical extremity of the cord. The spinal cord is suspended within its sheath or *theca* of dura mater by two lateral wing-like ligaments, termed the **ligamenta denticulata**. These extend outwards from the sides of the cord and are attached by a series of pointed or tooth-like processes to the inner surface of the theca of dura mater. Between the wall of the spinal canal and the dura mater there is a narrow interval, which is filled up by soft areolo-fatty tissue and numerous thin-walled veins arranged in a plexiform manner.

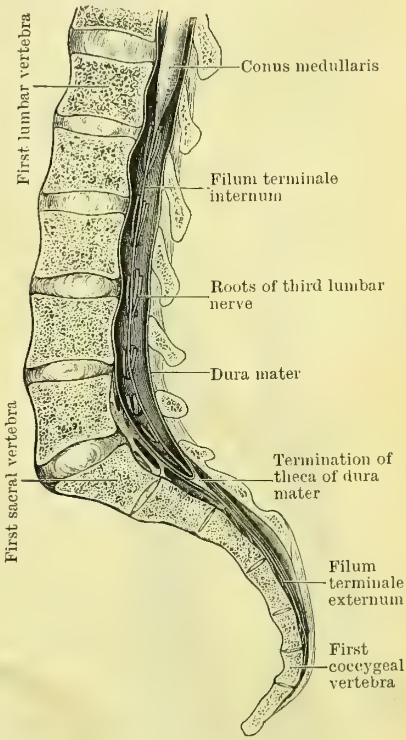


FIG. 315.—THE CONUS MEDULLARIS AND THE FILUM TERMINALE EXPOSED WITHIN THE SPINAL CANAL.

Thirty-one pairs of spinal nerves arise from the sides of the spinal cord. These are classified into eight cervical, twelve dorsal, five lumbar, five sacral, and one coccygeal; and according to the attachments of these groups of nerves the spinal cord is arbitrarily subdivided into a cervical, dorsal, lumbar, and sacral region. In employing these terms, therefore, to different districts of the cord, it must be understood that the regions are determined by the nerve attachments, and not by any direct relationship between these parts of the cord and the sections of the vertebral column which bear the same names.

Each spinal nerve is attached to the cord by a ventral and a dorsal root, and as these are traced to their central attachments they are seen to break up into a number of separate nerve fascicles or bundles, which spread out, in some cases very widely from each other, as they approach the side of the cord (Fig. 316). Each pair of nerves is therefore attached to a portion of spinal cord of some length, and such a portion, with its pair of nerves, receives the name of a "segment of the spinal cord." It must be clearly understood, however, that, in so far as the surface of the cord is concerned, there is absolutely no means of marking off one segment from another, except by the nerve attachments.

In the cervical and lumbar regions of the cord the nerve-roots are somewhat crowded together, so that little or no interval is left between the adjoining root fascicles of neighbouring nerves. In the dorsal region, however, distinct intervals may be observed, and the root fascicles are more loosely arranged. From this, it will be evident that the cord segments in different parts of the cord are not of equal length. In the cervical region the segments measure about 12 mm. in length, in the dorsal region from 20 to 24 mm., and in the lumbar region about 10 mm.

Owing to the great difference which exists between the length of the spinal cord and the length of the vertebral column, the farther we pass down the greater the distance becomes between the attachment of the various nerve-roots to the cord and the invertebral foramina through which the corresponding nerves leave the spinal canal. The lower nerve-roots, therefore, have to traverse the spinal canal for a considerable distance before they reach their apertures of emergence. It thus happens that the nerve-roots which spring from the lumbar and sacral regions of the cord attain a very great length and descend vertically in the lower part of the spinal canal in a bunch or leash, in the midst of which lie the conus medullaris and the filum terminale. This great bundle of nerve-roots receives the appropriate name of the **cauda equina**.

Enlargements of the Cord.—Throughout the greater part of the dorsal region, the spinal cord presents a uniform girth and a very nearly circular outline when seen in transverse section. In the cervical and lumbar regions, however, it shows marked swellings. The **cervical enlargement** (intumescentia cervicalis) is the more evident of the two. It begins very gradually at the upper end of the cord, attains its greatest breadth (12 to 14 mm.) opposite the fifth or sixth cervical vertebra, and finally subsides opposite the second dorsal vertebra. To this portion of the cord are attached the great nerves which supply the upper limbs. The **lumbar enlargement** (intumescentia lumbalis) begins at the level of the tenth dorsal vertebra, and acquires its maximum transverse diameter (11 to 13 mm.) opposite the last dorsal vertebra. Below, it rapidly tapers away into the conus medullaris. To the lumbar enlargement are attached the great nerves of the lower limbs.

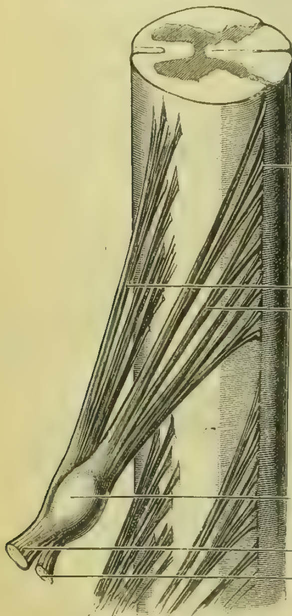


FIG. 316. —THE ROOTS OF ORIGIN OF THE SEVENTH DORSAL NERVE (semi-diagrammatic).

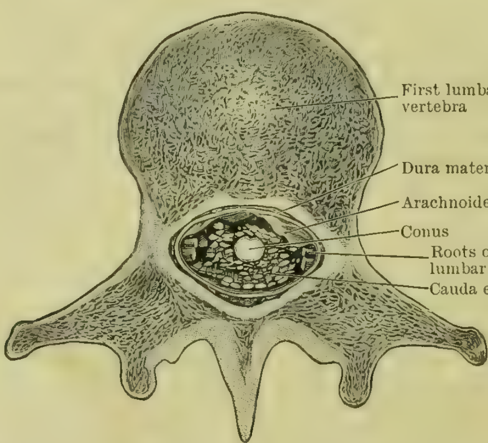


FIG. 317.—SECTION THROUGH THE CONUS MEDULLARIS AND THE CAUDA EQUINA AS THEY LIE IN THE SPINAL CANAL.

These enlargements of the cord are associated with the outgrowth of the limbs. In the earlier developmental stages of the spinal cord they are not present, and they only take form as the limbs become developed. In the lower mammalia their size corresponds with the degree of development of the limbs. Thus, in the long-armed orang and gibbon, the cervical swelling stands out with a remarkable degree of prominence. It is, however, interesting to note that although in the cetacea there are no visible hind-limbs, there is nevertheless a well-marked lumbar enlargement of the cord.

Fissures and Furrows of the Cord.—When cross-sections of the spinal cord are made, it is seen to be a bilateral structure which is partially subdivided into a right and left half by two median clefts—one upon the anterior and the other upon the posterior aspect. These clefts are termed the antero-median and the postero-median fissures, and they extend along the entire length of the cord. At the same

time it must be noted that these two median clefts present many points of difference. The **antero-median fissure** (fissura mediana anterior) is for the greater part of its length much shallower than the postero-median fissure. In the cervical and dorsal regions it only penetrates for a distance corresponding to somewhat less than a third of the antero-posterior diameter of the cord. Further, the antero-median cleft is much the wider and more apparent of the two, and the pia mater dips down into it and forms a fold or reduplication within it. The **postero-median fissure** (fissura mediana posterior) in the cervical and dorsal regions penetrates into the cord until it reaches a point somewhat beyond its centre. It is extremely narrow, and contains a single septum which is derived from ependymal and neuroglial elements, and is intimately connected with the adjacent sides of the two halves of the cord, between which it intervenes. The pia mater, which invests the surface of the cord, passes continuously over the postero-median fissure and sends no prolongation of any kind into it. In the lumbar region of the cord the postero-median fissure becomes shallower, whilst the antero-median fissure deepens, and ultimately in the lower part of the cord the two fissures present a very nearly equal depth.

The two halves of the cord, which are marked off from each other by the median fissures, may show trifling differences in the arrangement of the parts which compose them; but to all intents and purposes they are symmetrical. They are joined together by a more or less broad band or commissure, which intervenes between the two median fissures.

An inspection of the surface of each lateral half of the cord brings into view a longitudinal groove or furrow, at some little distance from the postero-median cleft, which extends along the whole length of the cord. Along the bottom of this groove the fascicles of the posterior nerve-roots enter the cord in accurate linear order. It is called the **postero-lateral sulcus** (sulcus lateralis posterior). There is no corresponding furrow on the forepart of each lateral half of the cord in connexion with the emergence of the fascicles of the anterior nerve-roots. These fascicles emerge irregularly over a broad strip of the surface of the cord, which corresponds in its width to the thickness of the subjacent extremity of the anterior horn of gray matter.

The postero-lateral groove subdivides each lateral half of the cord into a small **posterior column** (funiculus posterior) and a much larger **antero-lateral column**, and it is customary to arbitrarily map off the latter into a **lateral column** (funiculus lateralis) and an **anterior column** (funiculus anterior) by a line corresponding to the emergence of the outermost fascicles of the anterior nerve-roots.

In the cervical region a distinct longitudinal groove may be observed on the surface of the posterior column. It is placed rather nearer to the postero-median than to the postero-lateral furrow, and as it is traced down into the dorsal region it gradually becomes indistinct and finally disappears. This is called the **posterior paramedian groove**, and it marks on the surface the position of a septum of pia mater which dips into the cord and subdivides the posterior column into an outer part, termed the **funiculus cuneatus** or the **column of Burdach**, and an inner portion, which receives the name of the **funiculus gracilis** or the **column of Goll**.

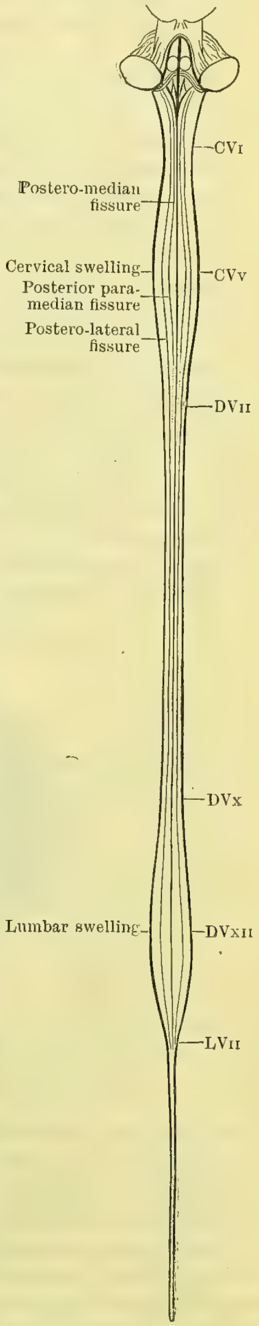


FIG. 318.—DIAGRAM OF THE SPINAL CORD AS SEEN FROM BEHIND.

CVI shows the level of the 1st cervical vertebra; CVV of the 5th cervical vertebra; DVII of the 2nd dorsal vertebra; DVX of the 10th dorsal vertebra; DVXII of the 12th dorsal vertebra; LVII of the 2nd lumbar vertebra.

Internal Structure of the Spinal Cord.

The spinal cord is composed of a central core of gray matter thickly coated on the outside by white matter. At only one spot does the gray matter come close to the surface, viz. at the bottom of the postero-lateral groove.

Gray Matter of the Cord.—The gray matter in the interior of the cord has the form of a fluted column, but it is customary to describe it as it appears in transverse sections through the cord. It then presents the appearance of the capital letter H. In each lateral half of the cord there is a semilunar or crescentic mass, shaped somewhat like a comma, the concavity of which is directed outwards and the convexity inwards. The two crescents of opposite sides are connected across the middle line by a transverse band, which receives the name of the **gray commissure** (commissura grisea). The postero-median fissure cuts through the cord until it reaches the gray commissure. The bottom of the antero-median fissure, however, is separated from it by an intervening strip of white matter, which is termed the **anterior white commissure** (commissura anterior alba). In the gray commissure may be seen the **central canal** of the cord (canalis centralis), which tunnels the entire length of the cord and is just visible to the naked eye as a minute speck. The portion of the gray commissure which lies behind the central canal is called the *posterior gray commissure* (commissura grisea posterior); whilst the portion in front receives the name of the *anterior gray commissure* (commissura grisea anterior).

Each crescentic mass of gray matter presents certain well-defined parts. The projecting portions which extend behind and in front of the connecting transverse gray commissure are termed respectively the posterior and the anterior cornua of gray matter (columnæ griseæ). These stand out in marked contrast to each other. The **anterior cornu** (columna grisea anterior) is short, thick, and very blunt at its extremity. Further, its extremity falls considerably short of the surface of the cord and is separated from it by a tolerably thick coating of white matter. Through this the fascicles of the anterior nerve-roots, as they emerge from the gray matter of the anterior horn, pass on their way to the surface. The thickened end of the anterior cornu is called the **caput cornu**, whilst the slightly constricted part close to the gray commissure is termed the **cervix cornu**. Throughout the greater part of the cord the **posterior cornu** (columna grisea posterior) is elongated and narrow, and is drawn out to a fine point, which almost reaches the bottom of the postero-lateral sulcus. This pointed extremity receives the name of the **apex cornu**; the slightly swollen part which succeeds it is the **caput cornu**; whilst the slightly constricted part adjoining the gray commissure goes under the name of the **cervix cornu**.

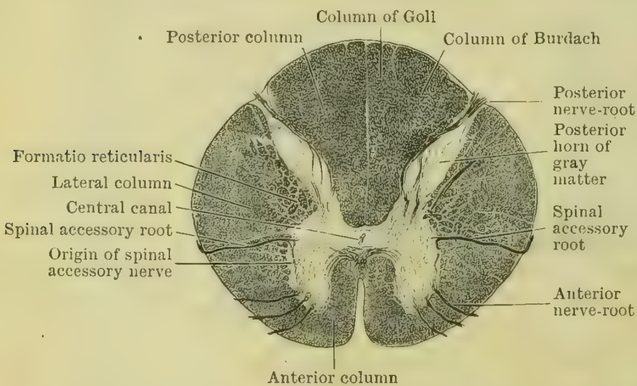


Fig. 319.—Transverse Section through the Upper Part of the Cervical Region of the Cord. (From a specimen prepared by the Weigert-Pal method, by which the white matter is rendered dark whilst the gray matter is bleached.)

The apex or tip of the posterior cornu differs considerably in appearance from the general mass of the gray matter. It is composed of a material which presents a lighter hue and has a somewhat translucent look. It is called the **substantia gelatinosa Rolandi**, and, when seen in transverse section, it exhibits a V-shaped outline and fits on the caput cornu like a cap.

A pointed and prominent triangular projection juts out from the external aspect of gray matter nearly opposite the gray commissure. This is the **lateral horn** (columna grisea lateralis), and is best marked in the upper dorsal region (Fig. 320, B). Traced upwards it becomes absorbed in the greatly expanded anterior horn

of the cervical swelling, but it reappears again in the upper part of the cord about the level of the third cervical nerve; followed in a downward direction it blends with the anterior horn in the lumbar swelling and contributes to the thickening of that cornu. It is interesting to note that it again reappears in the sacral region.

The gray matter is for the most part mapped off from the surrounding white matter with a considerable degree of sharpness; but in the cervical region, on the outer aspect of the crescentic mass and in the angle between the anterior and posterior horns, fine bands of gray matter penetrate the white matter, and, joining with each other, form a network the meshes of which enclose small islands of white matter. This constitutes what is called the **formatio** or **processus reticularis.** Although best marked in the cervical region, traces of the same reticular formation may be detected in the lower regions of the cord.

Characters presented by the Gray Matter in Different Regions of the Cord.—The gray matter is not present in equal quantity nor does it exhibit the same form in all regions of the cord. Indeed, there is reason to believe that every cord segment presents its own special characters in both of these respects. It is not necessary, however, in the present instance to enter into this matter with any degree of minute detail. It will be sufficient if we point out the broad distinctions which are evident in the different regions.

It may be regarded as a general law that, wherever there is an increase in the size of the nerves attached to a particular part of the cord, a corresponding increase in the amount of gray matter will be observed. It follows from this that the regions where the gray matter bulks most largely are the lumbar and the cervical swellings. The great nerve-roots which go to form the nerves of the large limb-plexuses enter and pass out from those portions of the cord. In the dorsal region there is a reduction in the quantity of gray matter in correspondence with the smaller size of the dorsal nerves.

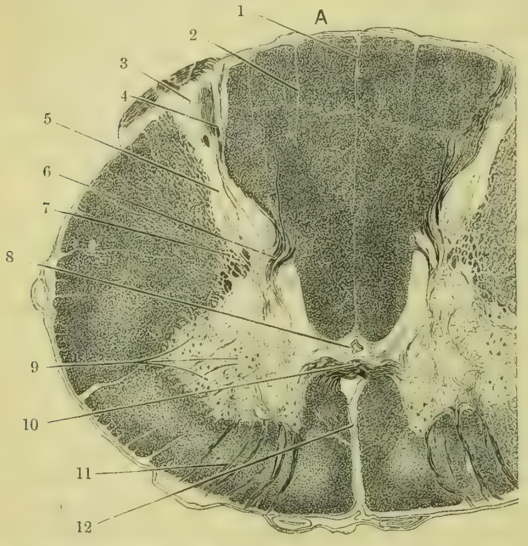
In the *dorsal region* (Fig. 320, B) both horns of gray matter are narrow, although the distinction between the anterior horn and the still more attenuated posterior horn is sufficiently manifest. In the *cervical region* (Fig. 320, A) the contrast between the cornua is most marked; the anterior horn is of great size and presents a very broad surface towards the anterior aspect of the cord, whilst the posterior horn remains narrow. In the *lumbar region* (Fig. 320, C), on the other hand, the difference in the breadth of the two gray horns is not so marked, owing to a broadening out of the posterior horn. The increase in the quantity of gray matter in the cervical swelling is chiefly confined to the anterior horns, whilst in the lumbar swelling it takes place in both horns. In the lower part of the *conus medullaris* the gray matter in each lateral half of the cord assumes the form of an oval mass joined to its fellow of the opposite side by a thick gray commissure. Here almost the entire bulk of the cord consists of gray matter, seeing that the white matter is reduced to such an extent that it forms only a thin coating on the outside.

White Matter of the Spinal Cord.—In transverse sections of the cord the three columns into which the white matter is subdivided become very apparent. The **posterior column** is wedge-shaped, and lies between the postero-median fissure and the posterior horn of gray matter. The **lateral column** occupies the concavity of the gray crescent. Behind, it is bounded by the posterior horn of gray matter and the postero-lateral sulcus, whilst in front it extends as far as the outermost fasciculi of the anterior nerve-roots as they pass out from the anterior gray horn. The **anterior column** includes the white matter between the antero-median fissure and the anterior horn of gray matter, and also the white matter which separates the broad extremity of the anterior gray cornu from the surface of the cord. This latter portion of the anterior column is traversed by the emerging fascicles of the anterior nerve-roots.

In cross-sections of the cord the partition of pia mater, which dips in at the posterior paramedian groove and divides the posterior column into the column of Goll and the column of Burdach, is very strongly marked in the cervical region; but as it is traced downwards into the dorsal region it becomes shorter and fainter, and finally disappears altogether at the level of the eighth dorsal nerve. Below

this point there is absolutely no visible demarcation of the posterior column into two parts.

The white matter is not present in equal quantity throughout the entire length of the cord. It increases steadily from below upwards, and this increase is most

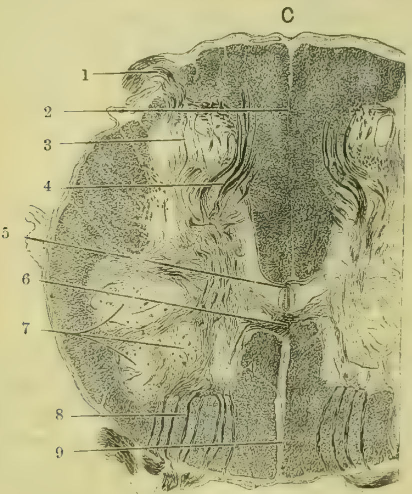


A.—Cervical region—at the level of the fifth cervical nerve. (From a specimen prepared by Dr. A. Bruce.)

1. Postero-median fissure.
2. Paramedian septum.
3. Postero-lateral groove.
4. Posterior nerve-root.
5. Substantia gelatinosa Rolandi.
6. Root-fibres entering gray matter.
7. Formatio reticularis.
8. Central canal.
9. Groups of ventral cells.
10. Anterior commissure.
11. Anterior nerve-root.
12. Antero-median fissure.

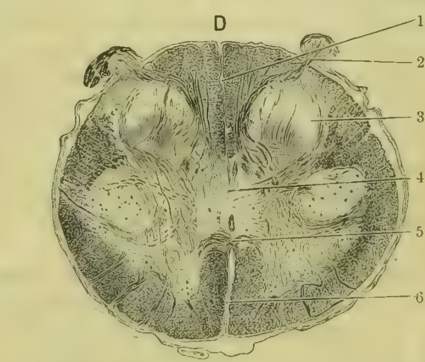
B.—Through the mid-dorsal region.

1. Postero-median fissure.
2. Postero-lateral groove.
3. Posterior cornu.
4. Posterior vesicular column of cells.
5. Lateral cornu.
6. Central canal.
7. Anterior cornu.
8. Antero-median fissure.



C.—Through the lumbar region at the level of the fourth lumbar nerve.

1. Posterior nerve-root.
2. Postero-median fissure.
3. Substantia gelatinosa Rolandi.
4. Root-fibres entering gray matter.
5. Central canal.
6. Anterior commissure.
7. Groups of ventral cells.
8. Anterior nerve-root.
9. Antero-median fissure.



D.—Through the sacral region at the level of the third sacral nerve. (From a specimen prepared by Dr. A. Bruce.)

1. Postero-median fissure.
2. Posterior nerve-root.
3. Substantia gelatinosa Rolandi.
4. Posterior gray commissure.
5. Anterior commissure.
6. Antero-median fissure.

Fig. 320.—Section through each of the Four Regions of the Cord. (From specimens prepared by the Weigert-Pal method.)

noticeable in the lateral and posterior columns. In the lower part of the conus medullaris the amount of gray matter is actually greater than that of the white matter: but very soon this state of affairs is changed, and in the lumbar region the proportion of gray to white matter is approximately as 1 : 2.1; in the dorsal region

as 1 : 5 ; and in the cervical region as 1 : 5·1. When it is remembered how the gray matter expands in the lumbar and cervical regions, and how greatly it becomes reduced in the dorsal region, the significance of these figures will become more apparent.

Summary of the Chief Characters presented by the Cord in its Different Regions.

Cervical Region.	Dorsal Region.	Lumbar Region.	Sacral Region.
In transverse section, **outline of cord** transversely oval; in the middle of the cervical swelling the transverse diameter being nearly one-third longer than the antero-posterior diameter.	In transverse section, **outline of cord** more nearly circular; but still the transverse diameter is greater than the antero-posterior diameter.	In transverse section, **outline of cord** more nearly circular than in dorsal region.	In transverse section, **outline of cord** nearly circular, but still somewhat compressed from before backwards.
Postero-median cleft very deep, extending beyond the centre of cord: **antero-median cleft** shallow.	**Postero-median cleft** very deep, extending beyond centre of cord: **antero-median cleft** shallow.	**Postero-median cleft** not nearly so deep as in regions above: **antero-median cleft**, on the other hand, much deeper.	**Postero-median** and **antero-median clefts** of equal depth.
Gray matter greatly increased in quantity in the cervical swelling: anterior horn thick and massive; posterior horn slender in comparison. Lateral horn only evident above the level of the fourth cervical nerve. Formatio reticularis strongly marked.	**Gray matter** greatly reduced in quantity. Both horns exceedingly slender. Lateral horn well marked. Formatio reticularis scarcely apparent.	**Gray matter** greatly increased in the lumbar swelling. Both horns very thick and massive. Lateral horn absorbed in anterior horn. Formatio reticularis absent.	Both horns of **gray matter** very thick and massive. Lateral horn apparent. No formatio reticularis.
White matter in great quantity, and especially massed in the lateral and posterior columns.	**White matter** less in quantity than in cervical region, but bulking largely in comparison with the quantity of gray matter.	**White matter** small in quantity in relation to higher regions, and very small in amount in relation to increased quantity of gray matter.	**White matter** very small in quantity in comparison with the gray matter.
Posterior paramedian groove and septum well marked.	**Posterior paramedian groove** absent; but the corresponding septum can be traced as low down as the eighth dorsal nerve.	No **posterior paramedian groove** or septum.	No **posterior paramedian groove** and no corresponding septum.
Central canal considerably nearer the anterior surface than the posterior surface of the cord.	**Central canal** considerably nearer the anterior surface than the posterior surface of the cord.	**Central canal** in the centre of the cord.	**Central canal** in the centre of the cord.

Central Canal (canalis centralis).—As previously stated, the central canal is found in the gray commissure. It is a very minute tunnel, barely visible to the naked eye when seen in transverse section, and it traverses the entire length of the cord. Above, it passes into the medulla oblongata, and finally opens into the fourth ventricle of the brain; below, it is continued for a variable distance into the filum terminale, and in this it ends blindly. Only in the lumbar region does the central canal occupy the centre of the cord. Above this level, in the dorsal and cervical regions, it lies very much nearer the anterior than the posterior aspect of the cord; whilst below the lumbar region, as it is traced down into the conus medullaris, it inclines backwards and approaches the posterior aspect of the cord. The calibre of the canal likewise varies somewhat in different parts of the cord. It is narrowest in the dorsal region; and in the lower part of the conus medullaris it expands into a distinct fusiform dilatation (very nearly 1 mm. in transverse diameter), which is termed the **ventriculus terminalis** (Krause).

The central canal is lined by a layer of ciliated columnar cells, the deep tapering ends of which are prolonged into slender processes, which penetrate into the substance of the cord. These cells constitute the lining ependymal cells of the canal.

The central canal is of interest because it represents in the adult the relatively wide lumen of the early ectodermal neural tube from which the spinal cord is developed.

Filum Terminale.—The delicate thread to which this name is applied is continuous with the lower tapered end of the conus medullaris. It is easily distinguished by its silvery and glistening appearance from the numerous long nerve-roots (cauda equina) amidst which it lies. It is about six inches long, and down to the level of the second sacral vertebra it is inclosed with the surrounding nerve-roots within the theca of dura mater. Piercing the tapered and closed end of the theca at this point, and receiving an investment from it, the filum terminale proceeds downwards in the sacral canal, and finally receives attachment to the periosteum on the dorsal aspect of the coccyx (Fig. 315, p. 421). It is customary to speak of the filum as consisting of two parts, viz. the filum terminale internum and the filum terminale externum, or the part inside and the part outside the theca of dura mater.

The **filum terminale externum** is simply a fibrous thread, strengthened by the prolongation it receives as it pierces the dura mater. The **filum terminale internum** is largely composed of pia mater; but in its upper half it incloses the terminal part of the central canal, and around this a variable amount of the gray substance of the cord is prolonged downwards into the filum. When transverse sections are made through the upper part of the filum terminale internum some bundles of medullated nerve-fibres are observed clinging to its sides, and with these are associated some nerve-cells identical with those in the spinal ganglia. These represent rudimentary or aborted caudal nerves (Rauber).

Component Parts of the Gray Matter of the Spinal Cord.

Neuroglia enters largely into the constitution of the gray matter of the cord. It forms a bed within which the nervous elements are distributed. These nervous elements consist of (1) nerve-cells and (2) nerve-fibres—both medullated and non-medullated. The nerve-cells lie in small spaces within the neuroglia, whilst the nerve-fibres traverse fine passages the walls of which are formed of the same substance. The neuroglia is thus an all-pervading basis substance, which isolates more or less completely the nervous elements from each other, and at the same time binds them together into a consistent solid mass. In the gray matter of the cord we distinguish two different kinds of material, viz. the **substantia gelatinosa** and the **substantia spongiosa**. The substantia gelatinosa, as already mentioned, forms the apex of the posterior horn of gray matter, and in this situation it is called the **substantia gelatinosa Rolandi**. It is also present in the form of a thick ring around the central canal, and here it receives the name of the **substantia gelatinosa centralis**. The remainder of the gray matter constitutes the substantia spongiosa. The sub-

stantia gelatinosa stains more deeply with carmine, and has a more transparent or translucent appearance than the substantia spongiosa.

In transverse sections of the cord the substantia Rolandi, in the cervical and dorsal regions, presents the appearance of a V-shaped mass, embracing the extremity of the caput of the posterior horn of gray matter; in the lumbar region this cap assumes a semi-lunar outline.

In the substantia gelatinosa the neuroglia is present in large quantity, and in the Rolandic portion of it small nerve-cells are developed in considerable numbers. In the substantia centralis the nerve-cells are few in number, and the ring which it forms is traversed by the fine processes which proceed from the deep ends of the ependymal cells which line the central canal.

Nerve-Cells.—The nerve-cells are scattered plentifully throughout the gray matter, but perhaps not in such great numbers as might be expected when we note the enormous number of nerve-fibres with which they stand in relation. They are all, without exception, multipolar, and send off from their various aspects several branching protoplasmic processes or dendrites, and one axon, which becomes the axis cylinder of a nerve-fibre. In size they vary considerably, and it is generally admitted that the bulk of a nerve-cell has a more or less definite relation to the length of the axis cylinder which proceeds from it.

When the nerve-cells are studied in a series of transverse sections of the cord, it will be noticed that a large proportion of them are grouped in clusters in certain districts of the gray matter; and as these groups are seen in very much the same position in successive sections, it is clear that these cells are arranged in longitudinal columns of greater or less length. Thus we recognise (1) a ventral group or column of cells in the anterior horn of gray matter; (2) a lateral group or column in the lateral horn of gray matter, where this exists; and (3) a posterior vesicular column of cells (Clarke's column), forming a most conspicuous group in the mesial part of the cervix of the posterior horn in the dorsal region of the cord.

Other cells besides those forming these columns are scattered somewhat irregularly throughout the gray matter of the posterior horn and the part of the gray crescent which lies between the two horns; and although these also in some measure may be classified into groups, the arrangement thus effected is not of so definite a character as to justify us in dwelling upon it in the present instance.

Ventral Cell-Column and the Origin of the Fibres of the Anterior Nerve-Roots.—The ventral cell-group occupies the anterior horn of gray matter, and in it are found the largest and most conspicuous cells in the spinal cord. It extends from one end of the cord to the other. These ventral nerve-cells have numerous wide-spreading dendritic processes, and it is to be noticed that certain of these dendrites do not confine their ramifications to the gray matter. Thus, some of the cells along the mesial border of the anterior horn of gray matter send dendrites across the mesial plane in the anterior commissure to end in the anterior gray horn of the opposite side; whilst others, lying along the lateral or outer margin of the anterior horn of gray matter, send dendrites in amongst the nerve-fibres of the adjoining white matter.

The axons or axis cylinder processes of a large proportion of the ventral cells converge together; and, becoming medullated, form bundles which pass out from the gray matter, and through the white matter which separates the thick end of the anterior horn from the surface of the cord, to finally emerge as the fascicles of the anterior nerve-roots. These cells, then, are the sources from which the nerve-fibres of the anterior nerve-roots proceed, and in consequence they are frequently spoken of as the "motor cells" of the cord.

In the chick a few of the more deeply seated of the ventral cells, placed in the cervical part of the anterior horn of gray matter, send their axons backwards through the posterior horn to the postero-lateral groove. Here they emerge from the cord and constitute a small group of efferent nerve-fibres in the afferent posterior nerve-root. It is more than doubtful if any such fibres exist in the posterior nerve-root of the mammal (Sherrington).

The ventral cells are not scattered uniformly throughout the anterior horn of gray matter. They are aggregated more closely together in certain parts of the anterior horn,

and thus form sub-groups more or less perfectly marked off from each other. This is most evident in the cervical and lumbar swellings of the cord, where, in conformity with the large anterior nerve-roots which issue from the cord, the ventral cells are much more numerous than in the dorsal region, and where also certain of the motor cells are especially large in conformity with the great length of the efferent fibres which proceed from them for the supply of the distant muscles of the limbs.

Two such sub-groups of the ventral cells are easily recognised, viz. a mesial and a lateral. The **mesial group** occupies the inner or mesial part of the anterior gray horn, whilst the **lateral group** occupies the outer part of the anterior gray horn. In the cervical and lumbar enlargements of the cord the cells of the lateral group increase greatly in number and become massed together in two collections, viz. a set in front called the *ventro-lateral sub-group*, and a set behind and more deeply placed, which receives the name of the *dorso-lateral sub-group*.

It is thought by some that this grouping of the ventral column of cells stands in relation to the muscle-groups to which their axis cylinder processes are distributed.

Lateral Cell-Column.—In those regions of the cord where the lateral horn of gray matter is well marked a group of cells may be seen within it. In other districts of the cord the same cell-group may be detected, although it is not so distinctly represented.

Posterior Vesicular Column—Clarke's Column.—This occupies the posterior horn of gray matter and is the most conspicuous of all the cell-groups in the cord. It does not, however, extend along the whole length of the cord; indeed it is almost entirely confined to the dorsal region, and in consequence it is sometimes referred to as the "dorsal nucleus." Above, it begins opposite the seventh or eighth cervical nerve, whilst below, it may be traced to the level of the second lumbar nerve, where it disappears. In transverse section of the cord it presents an oval outline, and is seen in the inner part of the cervix of the posterior horn of gray matter immediately behind the gray commissure (Fig. B). On the outer side it is circumscribed by numerous curved fibres from the entering posterior nerve-root, and in the lower dorsal region of the cord (opposite the eleventh and twelfth dorsal nerves) it becomes so marked that it forms a bulging on the inner aspect of the posterior gray horn.

The cells of Clarke's column are large, and possess several dendritic processes. The axons enter the lateral column of white matter and there form a strand of fibres, which will later on be described under the name of the **direct cerebellar tract.**

In addition to the topographical subdivision of the nerve-cells of the cord indicated above, it is now usual to classify them according to the nature of the axons which proceed from them. Thus we have (1) the cells of Golgi or cells with short axons, and (2) cells with long axons.

The **cells of Golgi** possess axons which do not emerge from the gray matter, but bring neighbouring cells into touch with each other. The **cells with long axons** are of two kinds, viz. radicular cells and strand-cells.

The **radicular cells** are those from which the axon emerges from the cord in the shape of an efferent nerve-fibre. Thus the "motor cells" which supply the axis cylinder processes of the anterior nerve-roots belong to this class. The **strand-cells** are those which contribute their axons to the formation of those fibres which form certain of the strands or tracts which are found in the white matter of the cord.

Nerve-fibres in the Gray Matter of the Cord.—Nerve-fibres both of the medullated and non-medullated variety pervade every part of the gray matter. They are of three kinds, viz. (1) collaterals, (2) terminations of nerve-fibres, (3) axons given off by the cells. The nerve-fibres which compose the columns of white matter of the cord give off numerous fine collateral branches, which pass into the gray matter from all sides and finally end in relation with the nerve-cells. The majority of the nerve-fibres themselves, which thus give off collaterals, finally turn in and enter the gray matter, to end similarly. As already noted, the axons of the cells in the case of the cells of Golgi remain within the gray matter, but all the others emerge either for the purpose of entering a peripheral nerve or for the purpose of entering a strand of fibres in the white matter of the cord.

The nerve-fibres thus derived are interwoven together in the gray matter of the cord in a dense inextricable interlacement.

Component Parts of the White Matter of the Cord.

The white matter of the cord is composed of medullated nerve-fibres embedded in neuroglia. The fibres, for the most part, pursue a longitudinal course; and from the deep surface of the pia mater which surrounds the cord fibrous septa or partitions are carried in along vertical planes between the fibres, so as to form an irregular and very imperfect fibrous framework of support. The neuroglia is disposed in a layer of varying thickness around the cord, subjacent to the pia mater, and is carried into the cord so as to give a coating to both sides of the various pial septa. The neuroglia also is disposed around the various nerve-fibres, so that each of these may be said to lie in a canal or tunnel of this substance. The nerve-fibres are all medullated, but they are not provided with primitive sheaths. It is the medullary substance of the nerve-fibres which gives to the white matter its opaque, milky-white appearance. When a thin transverse section of the cord is stained in carmine and examined under the microscope the white matter presents the appearance of a series of closely-applied circles, each with a dot in the centre. The dot is the transversely divided axis cylinder of a nerve-fibre, and the dark ring which forms the circumference of the circle represents the wall of the neuroglial canal which is occupied by the fibre. The medullary substance is very faintly seen. It presents a filmy or cloudy appearance between the axis cylinder and the neuroglial ring.

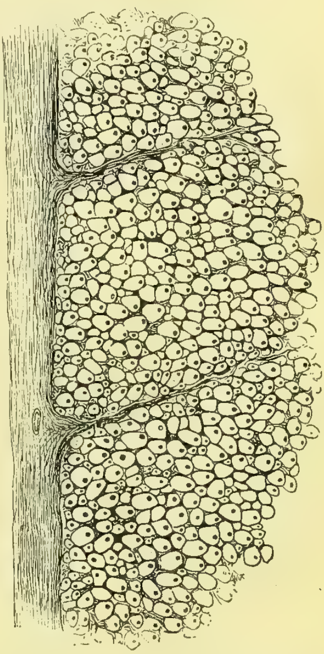


Fig. 321.—Transverse Section through the White Matter of the Cord, as seen through the microscope.

Arrangement of the Nerve-fibres of the White Matter in Strands or Tracts.—When the white matter of a healthy adult cord is examined the fibres which compose it are seen to vary considerably in point of size; and although there are special places where large fibres—or it may be small fibres—are present in greater numbers than elsewhere, yet as a rule both great and small fibres are mixed up together. Absolutely no evidence can be obtained in such a cord, by any means at our disposal, of the fact that the longitudinally-arranged fibres are grouped together in more or less definite tracts or strands, the fibres of which run a definite course and present definite connexions. Yet we know this to be the case, and the existence of these separate tracts has been proved both by physiological and by embryological investigation.

The **physiological evidence** depends on the fact that when a nerve-fibre is severed the part which is detached from the nerve-cell from which it is an offshoot degenerates, whilst the part which remains connected with the nerve-cell undergoes little or no change. This is called the law of "Wallerian" degeneration. Thus, if in a living animal one-half of the cord be cut across, and after a few weeks the animal be killed and the cord examined, it will be seen that there are degenerated tracts of fibres in the white matter, both above and below the plane of division; but, still further, it will also be manifest that the tracts which are degenerated above the plane of division are not the same as those which are degenerated in the part of the cord which lies below this level. The interpretation of this is obvious. The nerve-tracts which have degenerated above the plane of section are the offshoots of nerve-cells which lie in lower segments of the cord or in spinal ganglia below the plane of section. Severed from these nerve-cells, they undergo what is called ascending degeneration. The nerve-tracts, on the other hand, which have degenerated in the portion of the cord below the plane of division are the axons of cells which lie at a higher level than the plane of section, either in higher segments of the cord or in the brain itself. Cut off from the nerve-cells from which they proceed, they present an example of descending degeneration.

The **embryological evidence** we owe to Flechsig, and it is no less satisfactory. It depends upon the fact that nerve-fibres in the earliest stages of their development consist of naked axis cylinders, and are not provided with medullary sheaths. Further, the nerve-fibres of different strands assume the medullary sheaths at different periods. By examining the fœtal cord at

different stages of its development, it is a comparatively easy matter to locate the different tracts of fibres by evidence of this kind. Speaking broadly, the tracts which myelinate first are those which bring the cord into relation with the peripheral parts (skin, muscles, etc.); then those fibres which bind the various segments of the cord together; next, those which connect the cord with the cerebellum; and, lastly, the tracts which connect the cord with the cerebrum. The nervous apparatus for the performance of automatic movements is fully provided, therefore, before this is put under the control and direction of the higher centres. It by no means follows that in all the higher animals corresponding strands myelinate at relatively corresponding periods. Take the case of a young animal which from the time of its birth is able to move about and perform voluntary movements of various kinds in a more or less perfect manner, and compare it with the helpless new-born human infant which is only capable of exhibiting automatic movements. In the former the pyramidal tracts, or motor tracts, which descend from the cerebrum into the cord, and which are the paths along which the mandates of the will travel, myelinate at an early period; whilst in the human infant the corresponding fibres do not obtain their medullary sheaths until after birth. The study of the dates, therefore, at which the various strands of nerve-fibres myelinate not only gives the anatomist a means of locating their position in the white matter of the cord, but it also affords the physiologist most important information regarding their functions, and also the periods at which these functions are called into play.

Posterior Column of the Cord and the Posterior Roots of the Spinal Nerves.—In the cervical and upper dorsal regions of the cord the posterior column is divided by the posterior paramedian septum into the **tract of Burdach**, which lies externally and next the posterior horn of gray matter, and the **tract of Goll**, which lies internally and next the postero-median septum. The tract of Burdach is composed of nerve-fibres, which are for the most part larger than those entering into the formation of Goll's tract, and both tracts have a most intimate relation to the posterior nerve-roots; indeed, they are both almost entirely composed of fibres which enter the cord by these roots and then pursue a longitudinal course.

The nerve-fibres which form the posterior nerve-roots, on entering the cord along the postero-lateral groove, divide within the tract of Burdach into ascending and descending branches. These branches diverge abruptly from each other; and the former take an upward course, whilst the latter proceed downwards. The descending fibres are as a rule short, and soon turn inwards, to end in the gray matter of the cord. The ascending fibres vary greatly in length, and at varying distances from the point where the parent fibres enter the cord they turn inwards, to end in the gray matter. A small contribution of ascending fibres, however, from each posterior nerve-root, extends upwards to the upper end of the cord, to end in the medulla oblongata.

As each posterior nerve-root enters, its fibres range themselves in the outer part of the tract of Burdach close up against the posterior horn of gray matter. The nerve-fibres of the nerve-root next above take the same position, and consequently those which entered from the nerve immediately below are displaced inwards, and come to lie in the tract of Burdach nearer to the mesial plane. This process goes on as each nerve-root enters, and the result is that the fibres of the lower nerves are gradually pushed nearer and nearer to the postero-median septum in a successive series of lamellar tracts. Of course the greater proportion of the fibres, which are thus carried upwards from the posterior nerve-roots, sooner or later leave the posterior column and enter the gray matter, to end there in relation to some of its cells; but, as we have said, every posterior nerve-root sends a few fibres up the whole length of that portion of the cord which lies above, and thus the posterior column gradually increases in bulk as it is traced upwards, and in the upper reaches of the cord a tract of Goll becomes evident. This tract of Goll is composed of the long ascending fibres of the posterior nerve-roots, which have entered the lower segments of the cord. To put the matter differently, the fibres of the sacral roots are displaced inwards by the entering lumbar fibres, while the fibres of the lumbar roots are in their turn pushed inwards by the entering dorsal fibres, and, lastly, the fibres of the cervical roots displace the dorsal fibres. The difference between the tract of Goll and the tract of Burdach simply consists in this, that the former is composed of the fibres of posterior nerve-roots which have entered the cord at a lower level than those which enter into the formation of the column of Burdach. The fibres of Goll's tract, taking them as a whole, must therefore necessarily run a very much longer course.

Our knowledge of the constitution of the posterior columns of the cord is largely derived from studying the course of degeneration in monkeys, in which the cord has been cut across—either partially or completely. It would appear, from the examination of the human cord which has been injured or compressed, that the lamination of the

fibres entering from the series of posterior nerve-roots is not nearly so complete as in the case of the monkey.

Numerous collateral fibrils stream into the gray matter of the posterior horn both from the ascending and descending branches of the entering fibres of the posterior nerve-roots. These are classified into long and short collaterals. The **long collaterals** extend forward into the anterior horn of gray matter and end in relation to the ventral nerve-cells. The **short collaterals** end in relation to the nerve-cells in the substantia Rolandi, the nerve-cells of Clarke's column, and the other nerve-cells of the posterior horn (Fig. 320, p. 426).

Tract of Lissauer.—This is a small tract of nerve-fibres of minute calibre which assume their medullary sheaths at a comparatively late period. It is placed at the surface of the cord close to the postero-lateral furrow. It is formed by some of the outer fibres of the posterior nerve-roots, which do not enter the tract of Burdach, and which pass upwards in the cord close to the substantia gelatinosa Rolandi, in which they ultimately end.

Association Fibres in the Posterior Column.—But the whole of the fibres of the posterior column are not derived from the posterior nerve-roots. A few fibres exist in this column which have a different origin. In all probability they are derived from some of the cells of the gray matter of the cord, and pass upwards or downwards in the posterior column for a varying distance before they finally turn in to end in the gray matter at a higher or a lower level. These fibres, therefore, constitute links of connexion between different cord segments, and thus they are termed **association** or **longitudinal commissural fibres.** Our information regarding these fibres at present is somewhat defective; but it may be mentioned that it is probable that the "**comma**" **tract of Schultze**, in the deeper part of the posterior column, and the **descending septo-marginal tract** of Bruce, placed nearer the surface, belong mainly to this category.

Lateral Column of the Cord.—In the lateral column of the cord the well-established tracts are:—

1. The direct cerebellar tract.
2. The tract of Gowers.
3. The crossed pyramidal tract.

The remainder of the column goes under the name of the **lateral basis-bundle.**

The **direct cerebellar tract** (fasciculus cerebello-spinalis) is a band-like strand which lies in relation to the surface of the cord immediately in front of the postero-lateral groove. It is an ascending tract and is composed for the most part of coarse large nerve-fibres, which are derived from the nerve-cells of the posterior vesicular column (Clarke's column) in the posterior horn of gray matter. It is, therefore, not found through the whole length of the cord. It first appears in the lower part of the dorsal region; and as it ascends it gradually increases in size as it is joined by the axons of the cells of Clarke's column, which lie at higher levels. It finally enters the medulla oblongata, and through this proceeds to the cerebellum, in which it ends.

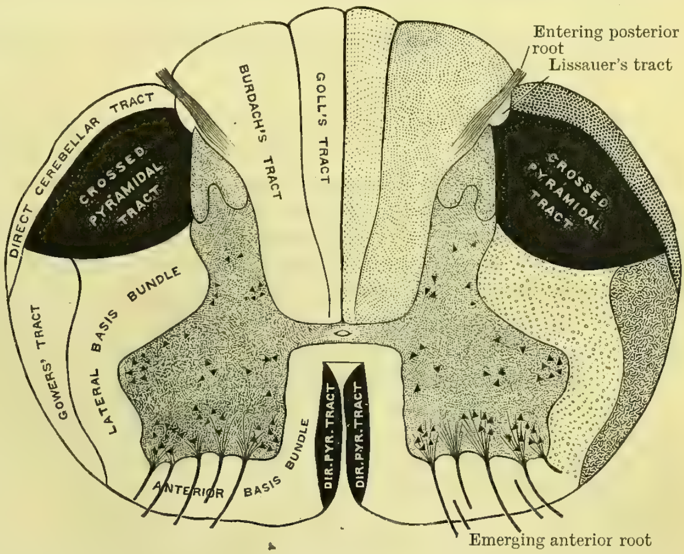


FIG. 322.—DIAGRAMMATIC REPRESENTATION OF A TRANSVERSE SECTION THROUGH THE SPINAL CORD.

The nerve tracts in the white matter and the clusters of nerve-cells in the gray matter are shown.

Gowers's tract (fasciculus antero-lateralis superficialis) lies in front of the direct

cerebellar tract, and, like it, next the surface of the lateral column. It is also an ascending tract, and it likewise (in part at least) ultimately reaches the cerebellum, although after leaving the cord it takes a different route to gain its destination. In transverse sections of the cord it presents a comma-shaped appearance, the thick part abutting against the direct cerebellar tract, and the narrower portion tapering forwards into the region of the emerging anterior nerve-roots. The tract of Gowers begins at a lower level in the cord than the direct cerebellar tract and it increases in volume as it is traced upwards. The fibres of this tract have probably their origin in the cells of the posterior horn of gray matter, but on this point there is at present no precise information.

The **crossed pyramidal tract** (fasciculus cerebro-spinalis lateralis) is a large well-defined descending tract, which lies immediately in front of the posterior horn of gray matter and subjacent to the direct cerebellar tract, which shuts it out from the surface of the cord. Below the point where the direct cerebellar tract begins the crossed pyramidal tract becomes superficial, and in this position it can be traced as low as the fourth sacral nerve, at which level it ceases to exist as a distinct strand. The crossed pyramidal tract is composed of an admixture of both large and small fibres. These arise in the brain from the large pyramidal cells of the motor or Rolandic area of the cerebral cortex, and pass downwards through various subdivisions of the brain to gain the spinal cord. As they enter the cord they cross the mesial plane from one side to the other, and it thus happens that the crossed pyramidal tract in the right lateral column of the cord has its origin in the cortex of the left cerebral hemisphere, and *vice versa*. As the tract descends in the cord it gradually diminishes in size; and this is due to the fact that, as it traverses each spinal segment, numerous fibres leave it to enter the anterior horn of gray matter, and end in connexion with the ventral motor cells from which the fibres of the anterior nerve-roots arise. The entire strand is ultimately exhausted in this way. Numerous collateral fibrils spring from the pyramidal fibres, and, entering the gray matter, end in a similar manner, and in this way a single pyramidal fibre may be connected with several spinal segments before it finally ends. The crossed pyramidal tract must be regarded as a great motor strand which brings the spinal motor apparatus under the control of the will.

Schäffer believes that many of the pyramidal fibres end in connexion with the cells of Clarke's column.

The **lateral basis-bundle** (fasciculus lateralis proprius) represents the remainder of the lateral column. Our information regarding it is still imperfect; but it would appear that its fibres are largely derived from the cells situated in all parts of the gray matter, and also from the nerve-cells of the opposite side of the cord. After a course of very varying length in the basis-bundle, these fibres turn inwards and re-enter the gray matter. Such fibres may thus be regarded as **inter-segmental association fibres** binding two or more segments of the cord together.

Anterior Column of the Cord.—One well-defined tract is situated in the anterior column. This is termed the direct pyramidal tract. The remainder of the column receives the name of the anterior basis-bundle.

The **direct pyramidal tract** (fasciculus cerebro-spinalis anterior) is usually a nerve-strand of small size which lies next the antero-median fissure. As a rule, it cannot be traced lower than the middle of the dorsal region of the cord. It is a descending tract and must be associated with the crossed pyramidal tract of the opposite side, seeing that both of these strands arise from the motor area of the cortex of the same cerebral hemisphere. From this, it must be clear that the direct pyramidal tract does not cross the mesial plane as it enters the cord, but descends on the side of the cord corresponding to the cerebral hemisphere in which it arises. All the same its fibres do not end in the same side of the cord, but at every step along the path of the strand they make use of the anterior commissure and cross to the opposite side of the cord, to terminate in relation to the opposite ventral motor cells in the same manner as the crossed pyramidal fibres.

From this crossing of the pyramidal tracts, it results that the destruction of the fibres which compose them as they descend in one side of the brain must result in paralysis of the muscles supplied by the efferent nerves of the opposite side of the cord.

It is well to note that the fibres of both pyramidal tracts are not medullated until the time of birth. They are the latest of all the cord-tracts to myelinate.

The **anterior basis-bundle** (fasciculus anterior proprius), like the lateral basis-bundle, is composed largely of fibres which arise from the cells of the gray matter of the cord, and act the part of **intersegmental association fibres.**

Summary of the Constitution of the White Matter of the Cord.—The white columns of the cord are formed of two kinds of nerve-fibres:—

1. Those which enter the cord from without.
2. Those which take their origin from the cells within the gray matter of the cord itself.

Under the first category we include (*a*) the greater part of the fibres of the posterior column (columns of Burdach and Goll), which arise from the cells of the spinal ganglia, and which enter the cord as the posterior nerve-roots; and (*b*) the crossed and direct pyramidal tracts which come from the motor cells of the cerebral cortex.

The fibres which arise within the gray matter of the cord may be classified thus: (*a*) Fibres which pass out from the cord as efferent nerves (anterior nerve-roots); (*b*) fibres which form long tracts and pass up the cord to enter the brain (direct cerebellar tract and the tract of Gowers); (*c*) fibres which form short tracts, linking together different segments of the cord (intersegmental association fibres in each of the three columns of the cord).

Anterior White Commissure.—The anterior commissure is composed of medullated nerve-fibres passing from one side of the cord to the other and entering the anterior horn of gray matter, and also the anterior column. It is to be regarded more as a decussation than as a commissure, and its width, which varies somewhat in different regions, fluctuates in correspondence with the diameter of the cord.

Amongst the fibres which cross in the anterior commissure may be mentioned: (1) The fibres of the direct pyramidal tract; (2) collaterals from both the ventral and lateral columns; (3) axons of many of the cells of the gray matter; (4) the dendritic processes of some of the mesial ventral cells.

Posterior Gray Commissure.—Although this is composed of gray matter with a large admixture of neuroglia, numerous transverse nerve-fibres pass through it, so as to bind the cells of one side of the cord to those of the other.

Development of the Spinal Cord.

In the chapter upon General Embryology it has been pointed out (p. 19) that the brain and cord first take shape in the form of a tube of ectoderm, which receives the name of the **neural tube.** Three expansions, placed one behind the other at the cephalic end of the tube, represent the early brain; whilst behind these primitive cerebral vesicles comes the elongated narrower part of the tube, which at this stage represents the spinal cord. By a developmental process, which we now have to study, the walls of this portion of the neural canal give rise to the various elements which build up the substance of the cord, whilst a portion at least of the primitive cavity is preserved as the central canal of the cord. The account which is here given of the development of the cord is taken almost entirely from the writings of Professor His of Leipzig.

When first formed, the neural tube is compressed from side to side and presents an oval outline in transverse section (Fig. 14, p. 20). The two lateral walls are very thick, whilst the narrow dorsal and ventral portions of the wall are thin, and are termed the **mid-dorsal** and **mid-ventral laminæ.** The cavity of the tube in transverse section appears as a narrow slit. At this stage the wall of the neural tube is formed of a series of elongated neuro-epithelial columnar cells, closely applied to each other and extending throughout the whole thickness of the wall. The inner ends of these long columnar cells unite to form a delicate membrane termed the **internal limiting membrane,** which lines the lumen of the tube, whilst their outer ends present a similar relation to an **external limiting membrane,** which invests the outer surface of the tube. The name of **spongioblasts** is given to these cells, and they soon develop in such a manner as to form the sustentacular framework of the growing cord. Between their inner parts, immediately subjacent to the internal

limiting membrane, a series of clefts or open spaces are formed, in which appear large numbers of round cells called **germinal cells**. The precise origin of these germinal cells is not at present satisfactorily established; but they rapidly increase in number, and in the human embryo of four weeks they are seen to form an almost continuous layer beneath the internal limiting membrane. It is well to note, however, that in the thin mid-dorsal and mid-ventral laminæ no germinal cells are formed. Here the wall remains purely spongioblastic. The peripheral portions of the spongioblasts likewise undergo a marked transformation. They give off branches or processes, and by the interlacement of these a sponge-like network with irregular meshes is formed in the outer portion of the wall of the neural tube. The entire sustentacular framework into which the spongioblasts are developed is termed the **myelosponge**.

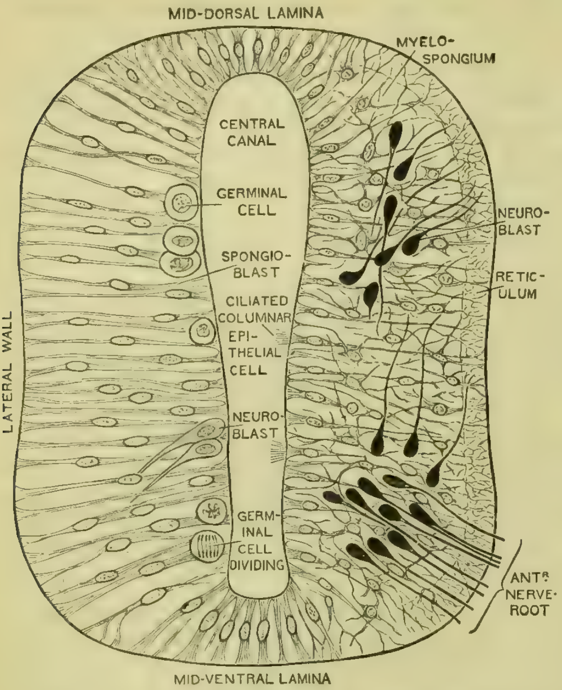


FIG. 323.—SCHEMA OF A TRANSVERSE SECTION THROUGH THE EARLY NEURAL TUBE (Young).

The left side of the section shows an earlier stage than the right side.

The numerous germinal cells which are placed in the clefts between the inner columnar portion of the myelosponge are the progenitors of the nerve-cells. Many of them show karyokinetic stages, and by their division they give rise to the **neuroblasts** or young nerve-cells. A neuroblast presents a very characteristic pear-shaped appearance. From the body of the cell a tapering process grows out, and this represents the early axis cylinder process or axon of the cell. But the crowds of neuroblasts which are thus formed do not remain in their early primitive position beneath the internal limiting membrane. They migrate outwards, and in the course of time they come to lie in the part of the myelosponge immediately adjoining the reticular meshwork, which is formed by the outer parts of the spongioblasts. Here their further outward migration is arrested. The reticular meshwork would almost appear to act as a sieve or a filter, which prevents their progress towards the periphery of the wall of the tube. It offers no impediment to the actively growing axons of the neuroblasts, however, which freely enter it and thread their way through it. At this stage the thick lateral wall of the neural tube presents three layers, viz. :—

1. An inner layer, formed by the columnar part of the myelosponge forsaken by the neuroblasts. This is termed the **ependymal layer**, and it ultimately resolves itself into the layer of columnar ciliated epithelial cells which lines the central canal of the cord.
2. An intermediate layer, in which the neuroblasts are present, and which is afterwards converted into the gray matter of the cord. This is called the **mantle layer.**
3. An outer layer, formed of the sponge-like meshwork of the outer parts of the original spongioblasts. Into this the axons of many of the neuroblasts are seen threading their way. This layer is ultimately transformed into the white matter of the cord, and at this stage it may be termed the **peripheral reticular layer.**

Alar and Basal Laminæ of the Lateral Wall of the Neural Tube.—From what has been said, it must be evident that the changes detailed above are confined to the thick lateral walls of the neural tube. In these alone do neuroblastic cells arise, whilst the thin mid-dorsal and mid-ventral laminæ remain spongioblastic throughout. But whilst these changes are going on the thick lateral wall begins to bulge outwards in an angular fashion, so as to widen the central cavity of the tube and become itself, along the line where the cavity is widest, demarcated into two portions—a narrow dorsal strip termed the **alar lamina** of His, and a broader ventral strip called the **basal lamina** of His. The cavity of the tube now appears on transverse section more or less lozenge-shaped, and

it is at the lateral angles of the lozenge that this subdivision of the lateral wall becomes evident.

This subdivision is a fundamental one, being present in the brain-part as well as the cord-part of the neural tube. By it the thick lateral wall is resolved into two longitudinal strips (the alar and basal laminæ), which extend along the whole length of the tube, and which present definite and precise relations with the entering and emerging roots of the various cranial and spinal nerves. Confining our attention to the spinal cord, the posterior nerve-root is seen to enter the alar lamina, whilst the anterior nerve-root takes origin within and emerges from the basal lamina.

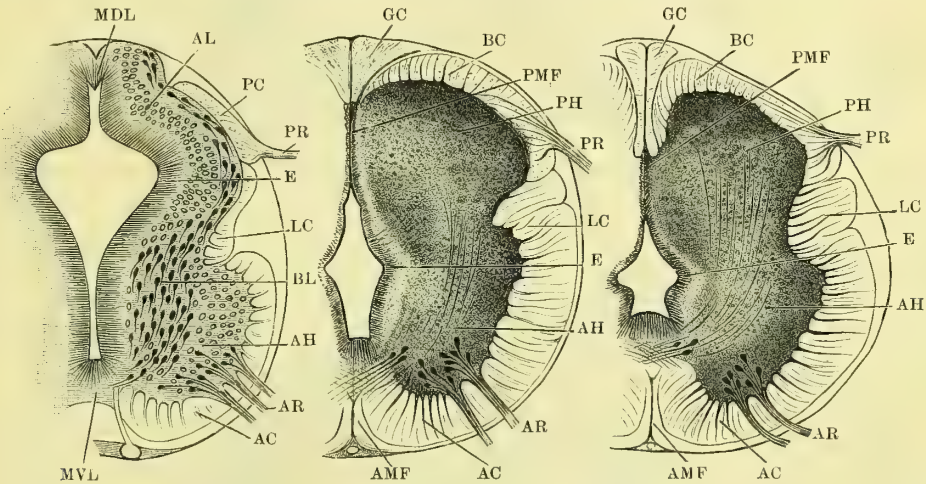


Fig. 324.—Three Stages in the Development of the Spinal Cord (His).

AC. Anterior column.
AH. Anterior horn of gray matter.
AL. Alar lamina.
AMF. Antero-median fissure.
AR. Anterior nerve-root.
BC. Column of Burdach.
BL. Basal lamina.
E. Ependyma.
GC. Column of Goll.
LC. Lateral column.
MDL. Mid-dorsal lamina.
MVL. Mid-ventral lamina.
PC. Early posterior column.
PH. Posterior horn of gray matter.
PMF. Postero-median fissure.
PR. Posterior nerve-root.

Further Development of the Gray and White Matter of the Cord.—In the ventral part of the basal lamina the mantle layer thickens into a mass, which is readily recognised as the rudiment of the anterior horn of gray matter, and in this neuroblastic cells congregate in much larger numbers than elsewhere. Further, these neuroblastic cells begin to arrange themselves into groups, and the axis cylinder processes of a large proportion of them converge and form bundles of fibres, which penetrate into the peripheral layer, and finally pierce the external limiting membrane, to emerge as the fascicles of the anterior nerve-roots. Behind the anterior horn the mantle layer still remains very thin, and the neuroblasts are few in number. There is, therefore, at this stage no appearance of the posterior horn of gray matter. Many of the axons of the neuroblasts which occupy this region are seen curving forwards, and, after traversing the anterior horn, they find their way across the middle line in the mid-ventral lamina. In this manner is laid down, at a very early stage, the rudiment of the anterior white commissure of the cord.

The white matter of the anterior and lateral columns is gradually established by axons from various neuroblasts in different parts of the mantle layer, entering the peripheral reticular layer and taking a longitudinal course within it. The anterior horn is well coated with white matter, however, before the lateral column takes definite shape.

The posterior columns of white matter are formed in a totally different manner, viz. by the introduction into the cord of nerve-fibres from without. The fibres of the posterior nerve-roots coming from the spinal ganglia strike the outer surface of the alar lamina of the lateral wall of the neural tube, and, piercing the external limiting membrane, take a longitudinal course in the peripheral reticular layer. On cross section these fibres first appear as an oval bundle, which lies in the outer part of the alar lamina (Fig. 324, PC). This bundle is the rudiment of Burdach's column, and at first it has a somewhat loose connexion with the cord; but as the posterior horn of gray matter gradually takes shape, the bundle in question increases in volume, and, changing its position, comes to lie on the inner aspect of the posterior horn. The column of Goll gradually assumes form

between the tract of Burdach and the postero-median septum. Later on the lateral and anterior columns are increased in bulk by the descent into them of the pyramidal tracts from the brain.

The gray matter, in the first instance, is chiefly massed in the basal lamina; but as the posterior columns of white matter begin to take shape it extends backward, and in the course of time the posterior horns are developed.

The manner in which the dendritic processes of the neuroblasts are developed has been sufficiently described (p. 417). The ensheathment, also, of the axons by medulla has been referred to, and the fact that the different tracts of fibres receive their medullary sheaths at different periods mentioned. It is now only necessary to state that the order of myelinisation of the several tracts is as follows:—(1) Fibres of the anterior nerve-roots; (2) tract of Burdach; (3) fibres in the basis-bundles; (4) tract of Goll; (5) direct cerebellar tract; (6) tract of Gowers; (7) pyramidal tracts (Kahler).

Development of the Median Fissures and of the Central Canal.—As the anterior horns of gray matter covered by the anterior columns of white matter increase in size, the anterior surface of the cord on either side of the mesial plane bulges forwards, and the antero-median fissure is produced as the natural result.

The manner in which the postero-median fissure comes into existence is not fully understood, but the majority of embryologists believe that it is produced by the approximation and fusion of the walls of the posterior part of the primitive cavity of the neural tube. The postero-median septum would thus appear to be formed of spongioblastic tissue.

If the above view of the formation of the postero-median fissure be correct, it must be evident that the central canal of the cord does not represent the whole of the primitive cavity of the early neural tube, but only the anterior portion of it.

Among those observers who do not hold that the central canal and posterior fissure have this mode of origin the most prominent is Professor A. W. Robinson, of King's College; and he has brought forward evidence which seems to indicate that it is doubtful if the fusion of the walls of the posterior part of the canal, referred to above, takes place. Certainly the arrangement of the ependymal elements of the postero-median septum, as seen in the preparations of Cajal and v. Lenhossek, are extremely difficult to understand on the fusion theory. They run in the antero-posterior direction, whereas, if fusion has taken place, most of them would present a transverse arrangement, and thus lie at right angles to the postero-median septum.

THE BRAIN OR ENCEPHALON.

The **brain** is the enlarged and greatly modified upper part of the cerebrospinal nervous axis. It is surrounded by the same membranes that envelop the spinal cord (viz. the dura mater, the arachnoid mater, and the pia mater), and it almost completely fills up the cavity of the cranium. So closely, indeed, is the skull capsule moulded upon the brain that the impress of the latter is almost everywhere evident upon the deep surface of the cranial wall. The relations, therefore, of cranium to brain are totally different from those presented by the vertebral canal to the spinal cord. As we have noted, the cord occupies only a part of its bony case; and there is not only a wide and roomy space between the arachnoid mater and pia mater, but also an interval of some width between the dura mater and the walls of the vertebral canal.

General Appearance of the Brain.—When viewed from above the brain presents an ovoid figure, the broad end of which is directed backwards. Its greatest transverse diameter is usually found in the neighbourhood of that part which lies between the two parietal eminences of the cranium. The only parts which are visible when the brain is inspected from this point of view are the two convoluted **cerebral hemispheres.** These present an extensive convex surface, which is closely applied to the deep aspect of the cranial vault, and are separated from each other by a deep median cleft, termed the **great longitudinal fissure**, which extends from the front to the back of the brain.

The inferior aspect of the brain is usually termed the "base." It presents an uneven and irregular surface, which is more or less accurately adapted to the inequalities on the floor of the cranium. Upon this aspect of the brain some of its main subdivisions may be recognised. Thus behind is seen the short cylindrical portion, called the **bulb** or **medulla oblongata**, through which, at the foramen magnum,

the brain becomes continuous with the spinal cord. The bulb lies on the ventral aspect of the cerebellum, and occupies the vallecula or hollow which intervenes between the two cerebellar hemispheres. The **cerebellum** is a mass of considerable size which is placed below the hinder portions of the two cerebral hemispheres. It

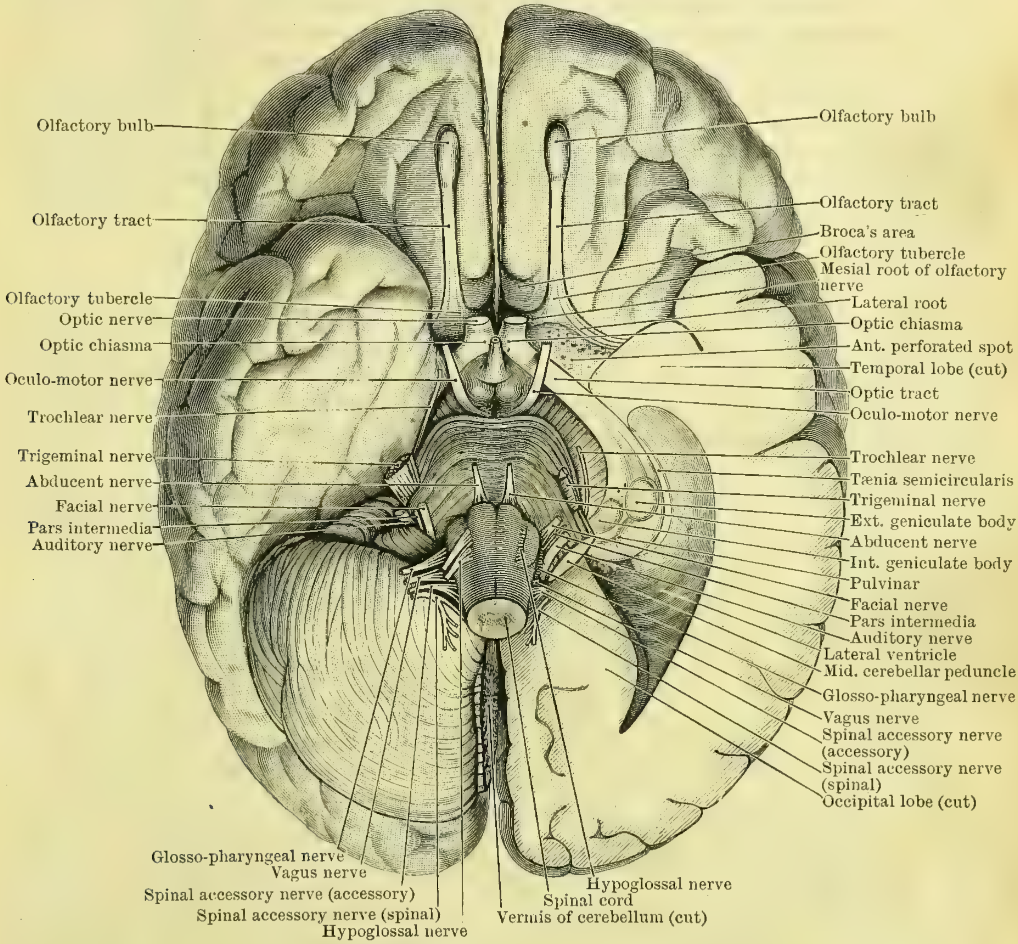


FIG. 325.—THE BASE OF THE BRAIN (A. M. Paterson).

The under part of the left temporal and occipital lobes has been sliced off so as to open into the lateral ventricle. The left hemisphere of the cerebellum has also been removed.

is easily recognised on account of the closely-set, curved, and parallel fissures which traverse its surface. Above the medulla, and in close connexion with it, is a prominent white elevation called the **pons Varolii**. Immediately in front of the pons there is a deep hollow or recess. This is bounded behind by the pons Varolii, on either side by the projecting temporal lobe of the cerebral hemisphere, and in front by the orbital portions of the frontal lobes of the cerebral hemispheres. Passing out from either side of the fore-part of this recess is the deep Sylvian fissure which intervenes between the pointed and projecting extremity of the temporal lobe and the frontal lobe of the cerebrum, whilst in the middle line in front the great longitudinal fissure, which separates the frontal portions of the cerebral hemispheres, opens into it.

Within the limits of this deep hollow, in the base of the brain, two large rope-like strands, the **crura cerebri**, may be seen issuing from the upper aspect of the pons Varolii. Placed close together as they emerge from the pons, these crura diverge as they proceed upwards and forwards, and finally each disappears by plunging into the corresponding side of the cerebrum. Turning round the outer side of each crus, where it enters the cerebrum, a flattened band termed the **optic tract** may be observed. These bands converge in the fore-part of the hollow, and

are finally joined together by a short commissural portion, termed the **optic chiasma**. The **optic nerve** is continued forwards and outwards, on either side, from the chiasma and tract.

The crura cerebri, the optic tract, and the optic chiasma enclose a deep rhomboidal or lozenge-shaped interval on the base of the brain, which is termed the **interpeduncular space.** Within the limits of this area the following parts may be seen as we pass from behind forwards: (1) the locus perforatus posticus; (2) the corpora mammillaria; (3) the tuber cinereum and the stalk of the pituitary body.

At its posterior angle, immediately in front of the pons Varolii, the interpeduncular space is very deep and is floored by a layer of gray matter, which is perforated by numerous small apertures. This is the **locus perforatus posticus.** Through the apertures which are dotted over its surface the small postero-mesial basal branches of the posterior cerebral artery enter the brain.

The **corpora mammillaria** are two small white pea-like eminences placed side by side in front of the locus perforatus posticus.

The **tuber cinereum** is a slightly raised field of gray matter, which occupies the interval between the anterior portions of the optic tracts in front of the corpora mammillaria. Springing from the fore-part of the tuber cinereum, immediately behind the optic chiasma, is the **infundibulum**, or the stalk which connects the pituitary body with the base of the brain.

Outside the limits of the fore-part of the interpeduncular space there is on either side a small depressed triangular field of gray matter, which leads outwards into the Sylvian fissure. It is perforated by the antero-mesial and the antero-lateral groups of basal arteries, and receives the name of the **locus perforatus anticus.**

General Connexions of the Several Parts of the Brain.—The medulla oblongata, the pons Varolii, and the cerebellum occupy the posterior cranial fossa, and they are separated from the cerebral hemispheres which lie above them by a partition of dura mater, termed the tentorium cerebelli. Further, they surround a cavity, a portion of the primitive cavity of the early neural tube, which is termed the **fourth ventricle** of the brain, and they all stand in intimate connexion with each other. The medulla is for the most part carried upwards into the pons Varolii; but at the same time two large strands from its dorsal aspect, termed the restiform bodies, are prolonged into the cerebellum, and constitute its **inferior peduncles**, or the chief bonds of union between the medulla and the cerebellum. The pons Varolii has large numbers of transverse fibres entering into its composition, and the great majority of these are gathered together on either side in the form of a large rope-like strand. This plunges into the corresponding hemisphere of the cerebellum, and constitutes its **middle peduncle.**

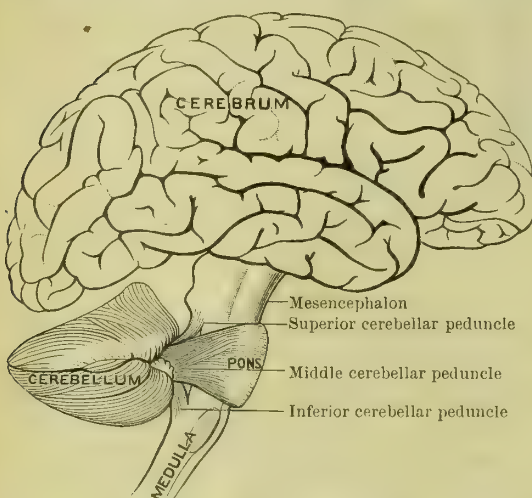


FIG. 326.—SCHEMA, showing the connexions of the several parts of the brain.

The cerebrum, which forms the great mass of the brain, occupies the anterior and middle cranial fossæ, and extends backwards into the occipital region above the tentorium and the cerebellum. The greater part of the cerebrum is formed by the cerebral hemispheres, which are separated from each other in the mesial plane by the great longitudinal fissure. At the bottom of this fissure is the **corpus callosum**, a broad commissural band which connects the two hemispheres with each other. Each hemisphere is hollow, the cavity in its interior being termed the **lateral ventricle** of the brain. Between and below the cerebral hemispheres, and almost

completely concealed by them, is the **inter-brain** or **diencephalon.** The principal parts forming this portion of the brain are two large masses of gray matter, termed the **optic thalami.** Between these is the **third ventricle** of the brain—a deep narrow cavity occupying the mesial plane. The third ventricle communicates with the lateral ventricles by two small apertures, called the **foramina of Monro.**

The cerebrum is connected with the parts in the posterior cranial fossa (pons Varolii, cerebellum, and bulb) by a narrow stalk called the **mid-brain,** or **mesencephalon.** The mid-brain is built up of the **crura cerebri,** passing from the pons Varolii to the cerebrum; the **corpora quadrigemina,** forming its dorsal part; the **superior cerebellar peduncles,** proceeding from the cerebellum to the cerebrum, etc. It is tunnelled by a narrow passage, the **aqueduct of Sylvius,** which extends between the fourth and third ventricles.

General Outline of the Development of the Brain.

The brain is developed from the expanded anterior portion of the primitive neural tube. In the section dealing with the general principles of Embryology it

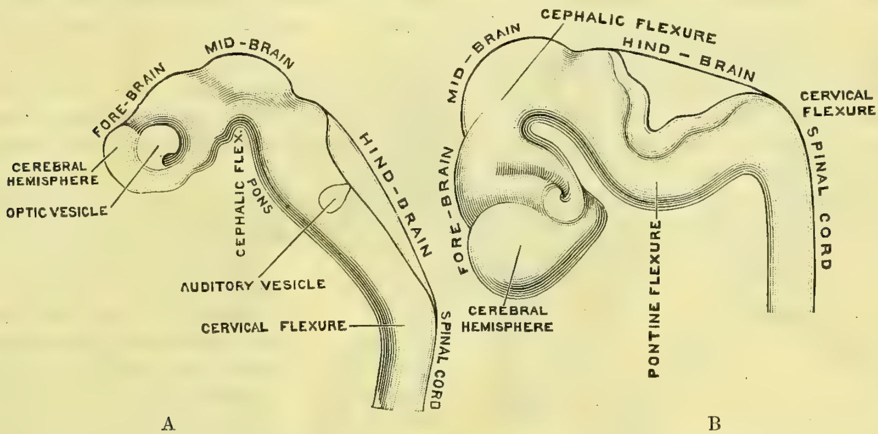


FIG. 327.—Two Stages in the Development of the Human Brain (after His).
A. Brain of an embryo of the third week. B. Brain of an embryo of five weeks.

has been pointed out that this is marked off by two constrictions into three primitive cerebral vesicles, which are termed respectively the hind-brain or rhombencephalon, the mid-brain or mesencephalon, and the fore-brain or prosencephalon.

Hind-brain or Rhombencephalon.—The hind-brain is the largest of the three primary expansions of the neural tube: indeed, it may be said that in the earlier stages of brain development it is larger than both of the other primary subdivisions taken together. The portion immediately adjoining the mid-brain is constricted, and is termed the **isthmus rhombencephali.** This is a very small part, forming the extreme upper end of the vesicle, and from its walls are developed the superior cerebellar peduncles and a thin lamina, which is stretched across the middle line between them, called the valve of Vieussens or the superior medullary velum. Immediately behind the isthmus the hind-brain expands suddenly, and then slowly and gradually tapers as it passes downwards towards the spinal cord part of the neural tube. Its junction with the latter is very early indicated by a sharp bend in the tube, which is termed the **cervical flexure.** The large portion of hind-brain which extends from the isthmus to the cervical flexure is usually considered as being composed of two parts, viz. an upper portion, termed the metencephalon, and an inferior portion, called the myelencephalon.

From the **metencephalon** are derived the cerebellum and pons Varolii. The cerebellum arises by a thickening of the dorsal wall of this portion of the vesicle, whilst the pons is derived from a thickening of the lateral and ventral walls. The **myelencephalon** gives origin to the bulb or medulla oblongata. This is chiefly formed by a thickening of the lateral walls of this part of the vesicle. These fall

away from each other in an outward direction, and thus the ventral angle between them becomes greatly opened up. The growth which leads to the formation of the bulb appears, therefore, to take place chiefly on the ventral aspect of the vesicle. The dorsal wall remains thin and epithelial, and undergoes little or no development into nervous elements.

The cavity of the original hind-brain is retained in the adult brain as the fourth ventricle; and from what has been said regarding the development of the different portions of the wall of the primitive hind-brain, it will be seen that in its lower or medullary part its dorsal wall or roof, to a large extent, remains epithelial.

The parts of the adult brain which are derived from the rhombencephalon or hind-brain are those which lie below the tentorium cerebelli in the posterior cranial fossa of the skull.

Mesencephalon or Mid-brain.—The mid-brain takes a much more prominent part in the formation of the early primitive brain than it does in the construction of the adult brain. It forms a very small part of the adult brain, and constitutes a stalk of connexion between the parts which are developed from the walls of the rhombencephalon and those which are developed from the walls of the prosencephalon or fore-brain. The entire wall of the mid-brain is transformed into nervous tissue. Thus, by the special development of the dorsal section of the wall, the corpora quadrigemina are formed. The lateral and ventral sections of the wall undergo a still more marked degree of growth-thickening, and the result is the formation of the two crura cerebri. The cavity of the mid-brain is retained as the narrow passage termed the aqueduct of Sylvius, which connects the third ventricle of the brain with the fourth ventricle.

Prosencephalon or Fore-brain.—In its early condition one of the leading peculiarities of the fore-brain is its great width. It extends outwards on either side for a considerable distance beyond the lateral walls of the mid-brain. These lateral expansions of the fore-brain are the **optic vesicles**, and at this stage they are in no way constricted off from the central part of the cavity. Soon, however, the central portion of the fore-brain begins to expand upwards and forwards, whilst the terminal portions of the optic vesicles likewise undergo enlargement; and the result is, that the originally single chamber shows subdivision into three parts, viz. a central portion or fore-brain proper, and two expanded optic vesicles, which are joined to the lower parts of the lateral aspects of the fore-brain proper by two short constricted tubular passages termed the optic stalks.

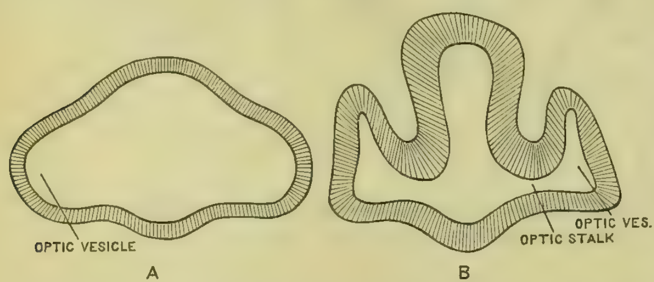


FIG. 328.—TWO CROSS SECTIONS THROUGH THE FORE-BRAIN.

A. Through the fore-brain of the early human embryo. B. Through the fore-brain and optic vesicles of a Lepidosteus embryo of eight days (after Balfour and Parker, modified).

The optic vesicle and the optic stalk become ultimately transformed into the retina of the eye-ball and the optic nerve. The series of changes which lead to this result are detailed in the section dealing with the anatomy of the organ of vision.

The fore-brain undergoes a series of remarkable developmental changes, the most striking of which is the formation of the cerebral hemispheres. The terminal or fore-portion of the fore-brain, in the first instance, expands in a forward and downward direction, and from the upper and lateral aspects of the new portion of the vesicle thus formed the cerebral hemispheres bulge outwards in the form of two hollow pouches. The hinder original part of the fore-brain is termed the **thalmamencephalon** or **diencephalon**, whilst the anterior part with the cerebral hemispheres, which protrude out from it, receives the name of **telencephalon**.

The side walls of the diencephalon become thickened into the two large masses of gray matter termed the optic thalami; the floor or ventral wall develops into

those structures which occupy the interpeduncular space in the base of the brain (viz. the posterior perforated spot, the corpora mammillaria, and the tubercinereum); whilst the roof or dorsal wall remains thin and epithelial, and undergoes no nervous development.

The hollow cerebral hemispheres soon outstrip all the other parts of the brain in their development. They expand not only in an upward and forward direction, but chiefly in a backward direction; and by their excessive growth backwards they gradually come to overlie the diencephalon, the mesencephalon, and at last the parts derived from the rhombencephalon. It thus comes about that, when the adult brain is viewed from above nothing but the cerebral hemispheres are visible—all the other parts of the brain lie under cover of them.

At first the cavity of each cerebral hemisphere is connected with the cavity of the front portion of the fore-brain by an exceedingly short but relatively wide passage. This is the early condition of the **foramen of Monro**. The fore-part of the fore-brain is now seen to be bounded in front between the two hollow cerebral hemisphere-pouches by a narrow thin strip, which represents the extreme anterior wall of the neural tube, and consequently it receives the name of **lamina terminalis**. The cavity of the fore-brain not only in its hinder diencephalic part, but also in its anterior part (*i.e.* the part from which the cerebral hemispheres bud out), persists as the third ventricle of the brain, whilst the cavities of the primitive cerebral hemispheres are represented in the adult by the lateral ventricles of the brain. The foramina of Monro, relatively much reduced in size, are preserved as narrow throats of communication between the lateral ventricles and the third ventricle. The olfactory lobes are formed as hollow outgrowths from the cerebral hemispheres.

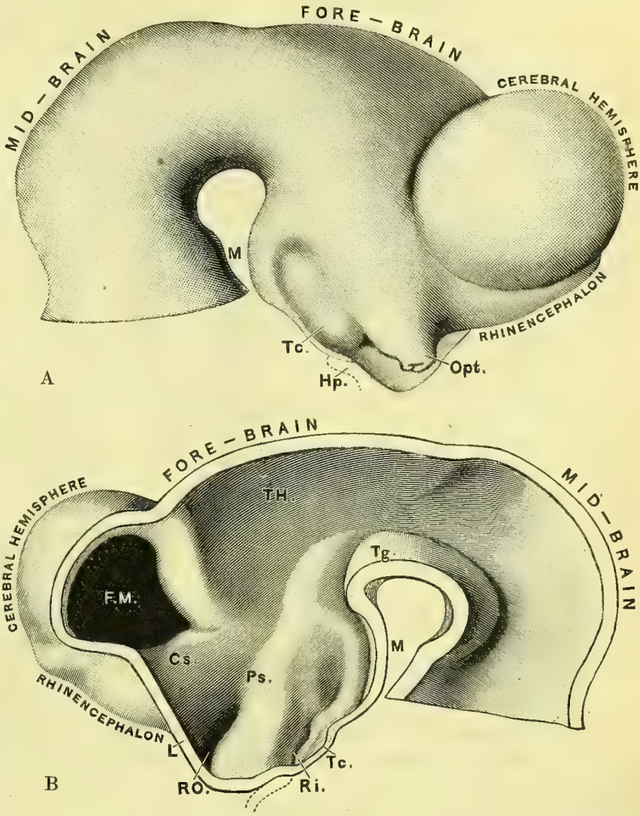


Fig. 329.—The Brain of a Human Embryo in the Fifth Week (from His).

A, Brain as seen in profile. B, Mesial section through the same brain.

M, Mammillary eminence; Tc, Tuber cinereum; Hp, Hypophysis (pituitary diverticulum from buccal cavity); Opt, Optic stalk; TH, Optic thalamus; Tg, Tegmental part of mesencephalon; Ps, Pars subthalamica; Cs, Corpus striatum; FM, Foramen of Monro; L, Lamina terminalis; RO, Recessus opticus; Ri, Recessus infundibuli.

Flexures of the Brain-tube.—At a very early period, and while the changes detailed above are being carried on, the cerebral portion of the neural tube becomes sharply bent upon itself at certain points. The first flexure which occurs is the **primary cephalic flexure**. It occurs in the region of the mesencephalon, and involves the entire head. The fore-brain becomes bent in a ventral direction round the fore-end of the notochord and the fore-gut, until the long axis of the fore-brain forms an acute angle with the long axis of the hind-brain and the ventral wall of the one comes to lie nearly parallel with the corresponding wall of the other. Through this curvature the mid-brain is considerably modified in form, and for a time it comes to occupy the most prominent and foremost part of the embryonic head.

The primary cephalic flexure is soon followed by the **cervical flexure.** This occurs at the junction of the hind-brain with the spinal cord. Here the entire head is bent in a ventral direction, and at the end of the fifth week the flexure is so pronounced that the cerebral and spinal cord portions of the neural tube meet each other at a right angle. In the later stages of development the cervical flexure becomes obliterated by the elevation of the head and the straightening of the neck of the embryo.

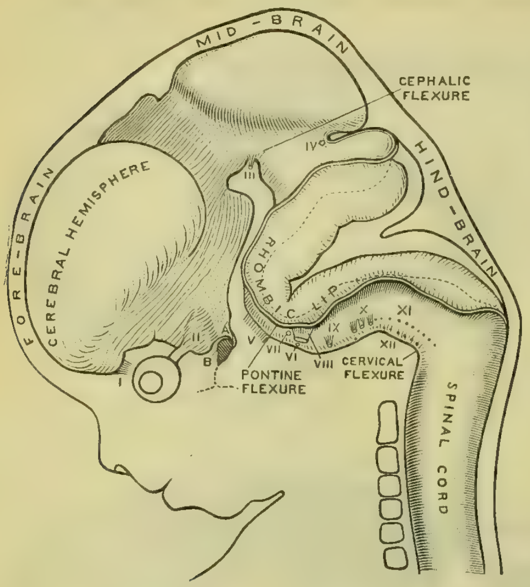


FIG. 330.—PROFILE VIEW OF THE BRAIN OF A HUMAN EMBRYO OF TEN WEEKS (His).

The various cranial nerves are indicated by numerals.

A, Cerebral diverticulum of pituitary body. B, Buccal diverticulum of pituitary body.

The third bend takes place in the region of the future pons Varolii (metencephalon), and is consequently termed the **pontine flexure.** It differs from the other flexures in being confined to the brain tube and in not in any way involving the entire head. Further, the bend is much more marked in the thick ventral wall than in the thin dorsal wall of the tube. The neural tube is doubled forwards on itself and the pons Varolii becomes developed in connexion with the summit of the curvature. In the further growth of the brain the pontine flexure becomes almost completely obliterated.

By reason of these curvatures the early brain assumes a sinuous, zigzag or S-shaped outline when viewed from the side, and the relationship of its various parts becomes materially altered. The essential factor at work in the production of the brain flexures is clearly the very unequal growth which takes place in different parts of the cerebral wall.

The Basal and Alar Laminæ of His.—It has been pointed out that, in the development of the spinal cord, each of the thick lateral walls of the neural tube is marked off into a dorsal or alar and a ventral or

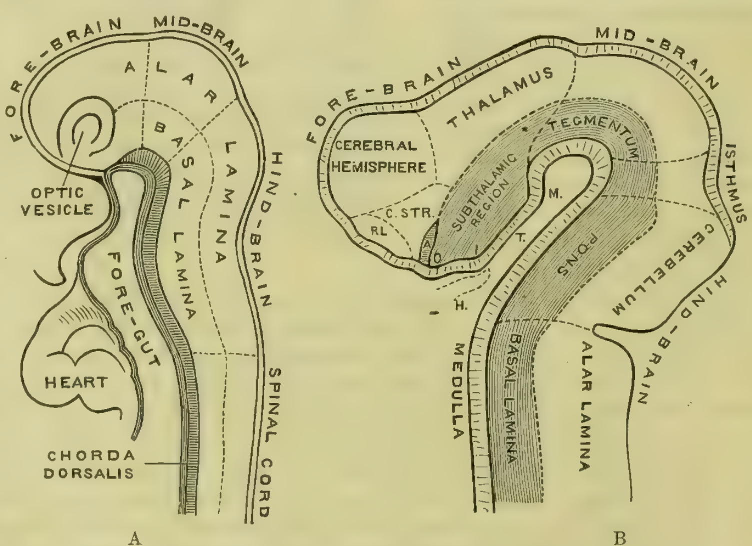


FIG. 331.—DIAGRAMS TO ILLUSTRATE THE ALAR AND BASAL LAMINÆ. In both cases the embryonic brain is represented in mesial section—(His).

A. The different subdivisions of the brain are marked off from each other by dotted lines, and the dotted line running in the long axis of the neural tube indicates the separation of the alar from the basal lamina of the lateral wall.

B. Mesial section through the brain of a human embryo at the end of the first month. Dotted lines mark off the different regions and also the alar and basal laminæ from each other.

H, Buccal part of pituitary body; RL, Olfactory lobe; C.STR, Corpus striatum; A, Entrance to optic stalk; O, Optic recess; I, Infundibular recess; T, Tuber cinereum; M, Mammillary eminence.

basal lamina. This subdivision is also noticeable in the cerebral part of the neural tube, and the furrow on the inner aspect of the lateral wall, which indicates this subdivision, can be traced even in the adult brain throughout the greater part of its length.

In the spinal cord the motor cells are gathered in the basal lamina in one long continuous column. In the brain the corresponding cells from which the efferent fibres of the cranial nerves are given off are also placed within the basal lamina, but they are arranged differently. They no longer form a continuous column, but are collected together in disconnected clusters termed the motor nuclei, and they do not extend higher up than the mid-brain. No motor nuclei occur in the basal lamina of the fore-brain. Indeed, the importance of the basal lamina diminishes as we pass from the lower to the higher parts of the brain.

In the rhombic or hind-brain the greater part of the medulla oblongata and of the pons Varolii is formed from the basal laminæ, whilst the cerebellum, with its superior and inferior cerebellar peduncles, is derived from the alar laminæ. In the mid-brain the crura cerebri are the derivatives of the basal laminæ, whilst the corpora quadrigemina are developed from the alar laminæ. In the fore-brain the subthalamic region and the optic vesicles are products of the growth of the basal laminæ, whilst the optic thalami and cerebral hemispheres spring from the alar laminæ.

The fact that the cerebellum and the cerebral hemispheres owe their origin to the alar laminæ is sufficient to show the predominant part which these laminæ play in brain development, and the higher we ascend in the animal scale the more pronounced does this predominance become.

The following table gives a summary of the various developmental processes which have been described in the foregoing pages:—

Encephalon or Brain	Rhombencephalon or Hind-brain (posterior cerebral vesicle)	Myelencephalon	Bulb or medulla oblongata Lower part of the fourth ventricle
		Metencephalon	Cerebellum Pons Varolii Upper part of the fourth ventricle
		Isthmus rhombencephali (narrow constricted part immediately adjoining the mesencephalon)	Superior cerebellar peduncles Valve of Vieussens
	Mesencephalon or Mid-brain (middle cerebral vesicle)	Mesencephalon or Mid-brain	Corpora quadrigemina Crura cerebri Aqueduct of Sylvius
	Prosencephalon or Fore-brain (anterior cerebral vesicle)	Thalamencephalon or Diencephalon	Optic thalami Subthalamic tegmental regions Pituitary and pineal bodies Structures in interpeduncular space Optic nerve and retina Hinder part of the third ventricle
		Telencephalon	Cerebral hemispheres Olfactory lobes Lateral ventricles Foramina of Monro Anterior portion of the third ventricle

THE PARTS OF THE ENCEPHALON DERIVED FROM THE HIND-BRAIN.

MEDULLA OBLONGATA OR BULB.

The **medulla oblongata** or **bulb** is the continuation upwards of the spinal cord. It is not more than one inch in length, and it may be regarded as beginning at the

decussation of the pyramidal tracts, which takes place about the level of the foramen magnum. From this it proceeds upwards in a very nearly vertical direction, and ends at the lower border of the pons Varolii. At first its girth is similar to that of the cord, but it rapidly expands as it approaches the pons, and consequently it presents a more or less conical form. Its ventral surface lies behind the grooved surface of the basilar portion of the occipital bone, whilst its dorsal surface is sunk into the vallecula of the cerebellum. The medulla oblongata is a bilateral structure, and this is indicated on the surface by a continuation upwards of the antero-median and postero-median fissures of the cord on the ventral and dorsal aspects of the medulla.

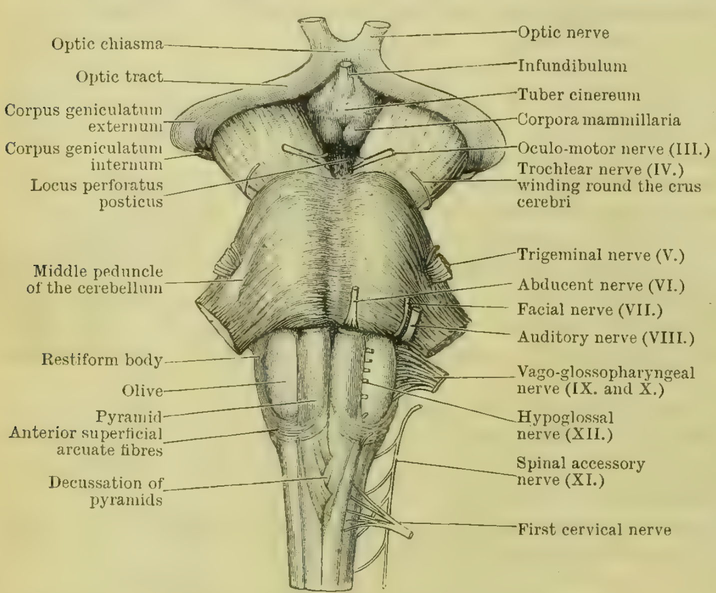


FIG. 332.—FRONT VIEW OF THE MEDULLA, PONS, AND MESENCEPHALON OF A FULL-TIME HUMAN FŒTUS.

The **antero-median groove** (fissura mediana anterior), as it passes from the cord on to the medulla, is interrupted at the level of the foramen magnum by several strands of fibres, which cross the mesial plane from one side to the other. This intercrossing is termed the decussation of the pyramids. Above this level the furrow is carried upwards to the lower border of the pons. Here it expands slightly and ends in a blind pit, which receives the name of the **foramen cæcum** of Vicq d'Azyr. The **postero-median fissure** (fissura mediana posterior) is only carried up on the lower half of the medulla. As it ascends it rapidly becomes shallower, and, halfway up, the central canal of the cord opens on the dorsal surface of the medulla. At this point the lips of the postero-median fissure are thrust apart from each other and constitute the boundaries of a triangular field, which is thus opened up on the dorsal aspect of the medulla. This triangular field is the lower part of the **fossa rhomboidalis**, or the floor of the fourth ventricle of the brain. The lower half of the medulla, containing as it does the continuation of the central canal of the cord, is frequently termed the **closed part of the medulla**; the upper half, above the opening of the canal, which by its dorsal surface forms the lower part of the floor of the fourth ventricle, is often called the **open part of the medulla.**

Deferring for the present the examination of the medullary part of the floor of the fourth ventricle, the appearance presented by the surface of each side of the medulla, from the antero-median fissure in front to the postero-median fissure and the lateral limit of the floor of the fourth ventricle behind, may now engage our attention. In the spinal cord the corresponding surface area is divided into three districts or columns by the emerging motor roots and the entering sensory roots of the spinal nerves. Of these the latter enter along the bottom of the postero-lateral groove, whilst the motor fascicles are spread over a relatively broad surface area and have no groove in connexion with their emergence from the cord. In the case of the medulla corresponding rows of nerve-fascicles enter and emerge from the surface of each side. The efferent fascicles are the root-bundles of the hypoglossal nerve, and they carry up the line of the anterior nerve-roots of the cord. In one respect, however, they differ; they emerge in linear order and along the bottom of a distinct furrow, termed the **antero-lateral furrow**, which

proceeds upwards on the surface of the medulla. The fascicles which carry up the line of the posterior nerve-roots on the surface of the medulla are the root-bundles of the spinal accessory, the vagus, and the glosso-pharyngeal nerves. These are attached along the bottom of a furrow which is the direct continuation upwards of the postero-lateral furrow of the cord, and therefore receives the name of the **postero-lateral furrow** of the medulla. The root-bundles of these nerves differ, however, in so far that they are not all composed of afferent fibres springing from ganglionic cells placed without and entering the medulla. Certain of them are purely efferent (spinal accessory roots), whilst others likewise contain a considerable number of efferent fibres, and are therefore to be regarded as mixed roots.

By the antero-posterior and the antero-lateral grooves, and also by the two rows of nerve fascicles attached along the bottom of these furrows, the surface of the medulla on each side is divided into three districts, viz. an anterior, a lateral, and a posterior, similar to the surface areas of the three columns on the side of the cord. Indeed, at first sight, they appear to be a direct continuation upwards of these three portions of the cord; this is not the case, however, because the fibres of the three columns of the cord undergo a rearrangement as they proceed upwards into the medulla.

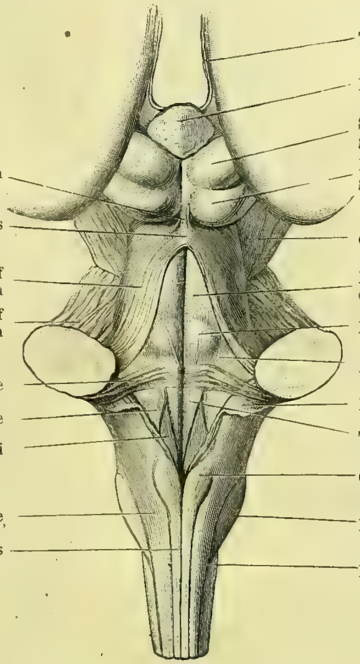


FIG. 333.—BACK VIEW OF THE MEDULLA, PONS, AND MESENCEPHALON OF A FULL-TIME HUMAN FŒTUS.

Anterior Area of the Medulla—Pyramid (pyramis).—The district between the antero-median fissure and the antero-lateral furrow, along the bottom of which the root-fascicles of the hypoglossal nerve issue from the medulla, receives the name of the pyramid. An inspection of the surface is sufficient to show that the pyramid is composed of a compact strand of longitudinally directed nerve-fibres. Tapering below, it expands and assumes a prominent appearance as it is traced upwards, and, finally reaching the lower border of the pons Varolii, it becomes slightly constricted and disappears from view by plunging into that portion of the brain. The two pyramids, separated from each other by the antero-median furrow, are the great motor strands of the medulla.

Although the pyramid at first sight appears to be continuous with the anterior column of the cord, only a very small proportion of the fibres contained in the latter are derived from the pyramid. This at once becomes manifest when the lips of the antero-median fissure are thrust apart at the place of junction between the cord and the medulla. The pyramid is then seen to divide at this level into two parts, viz. a small portion composed of a variable number of the outermost fibres of the pyramid, termed the **direct pyramidal tract**, and a much larger portion situated next the antero-median fissure, called the **crossed pyramidal tract.** The direct pyramidal tract is continued down into the anterior column of the cord, and in this it takes up a mesial position next the antero-median fissure. The crossed pyramidal tract is broken up into three or more coarse bundles, which sink backwards and at the same time cross the mesial plane, to take up a position

in the posterior part of the opposite lateral column of the cord. The term **decussation of the pyramids** (decussio pyramidum) is applied to the intercrossing of the corresponding bundles of the crossed pyramidal tracts of opposite sides.

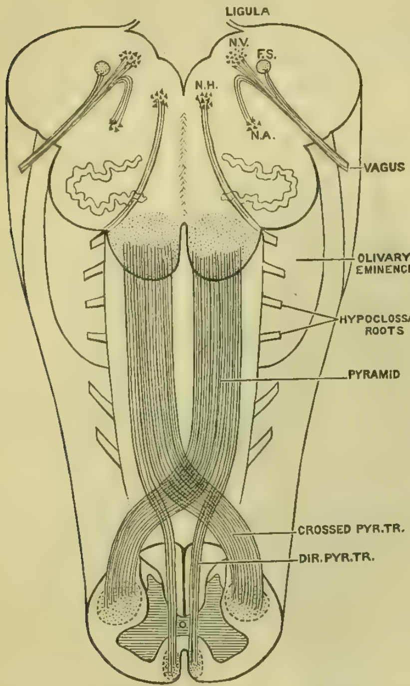


FIG. 334.—DIAGRAM OF THE DECUSSATION OF THE PYRAMIDS (modified from van Gehuchten). NH, Nucleus hypoglossi; NV, Vago-glosso-pharyngeal nucleus; FS, Fasciculus solitarius; NA, Nucleus ambiguus.

The direct pyramidal tract is, therefore, the only part of the pyramid which has a place in the anterior column of the cord. The much larger part of this column, termed the anterior basis-bundle, as it is traced up into the medulla is seen to be thrust aside by the decussating bundles of the crossed pyramidal tract. It thus comes to occupy a deep position in the substance of the medulla behind and to the outer side of the pyramid.

Lateral Area of the Medulla.—This is the district on the surface of the medulla which is included between the two rows of nerve-roots, viz. the hypoglossal roots in front, and the root-bundles of the spinal accessory, the vagus, and the glosso-pharyngeal nerves behind. It presents a very different appearance in its upper and lower parts. In its lower portion it simply appears to be a continuation upwards of the lateral area of the cord; in its upper part a striking oval prominence bulges out on the surface of the medulla, and receives the name of the **olivary eminence.**

The lower part of this district, however, is very far from being an exact counterpart of the lateral column of the cord. The large crossed pyramidal tract is no longer present, seeing that it forms in the medulla the greater part of the pyramid of the opposite side. Another small strand of fibres, viz. the direct cerebellar tract, prolonged upwards in the lateral column of the cord, gradually leaves this portion of the medulla. This tract lies on the surface, and is frequently visible to the naked eye as a white streak, which inclines obliquely backwards into the posterior district of the medulla to join its upper part, or in other words the restiform body. The remainder of the fibres of the lateral column of the cord, comprising the lateral basis-bundle and the tract of Gowers, are continued upwards in the lateral area of the medulla, and at the lower border of the olive the majority of these fibres disappear from the surface by dipping into the substance of the medulla under cover of that projection. A certain proportion of the fibres, however, are retained on the surface and travel upwards towards the pons in the interval, which exists between the hinder border of the olive and the roots of the vagus and glosso-pharyngeal nerves.

The **olivary eminence** (oliva) is a smooth oval projection which bulges out from the upper part of the lateral area of the medulla. Its long axis is vertical and is about half an inch long. It marks the position of the subjacent inferior **olivary nucleus,** a flexuous lamina of gray matter (nucleus olivaris inferior), which is only separated from the surface by a very thin layer of superficial white matter.

Posterior Area of the Medulla.—In its lower half this district is bounded behind by the postero-median fissure, and in its upper half by the lateral margin of the medullary part of the floor of the fourth ventricle of the brain. In front it is separated from the lateral area by the row of root-fascicles belonging to the spinal accessory, vagus, and glosso-pharyngeal nerves. As in the lateral area, we recognise a lower portion and an upper portion, which appear continuous, but in reality are quite distinct from each other.

The lower part of the posterior area corresponds more or less closely with

the posterior column of the cord. In the cervical part of the cord the posterior column is divided by the paramedian septum of pia mater into an inner column of Goll and an outer column of Burdach. These are prolonged upwards into the medulla, and in the lower part of the posterior area they stand out distinctly, and are separated from each other by a continuation upwards from the cord of the paramedian groove. In the medulla the inner of these strands is called the **funiculus gracilis,** whilst the outer one is designated the **funiculus cuneatus.** Each of these strands, when it reaches the level of the lower part of the floor of the fourth ventricle, ends in a slightly expanded bulbous prominence. The swollen extremity of the funiculus gracilis is called the **clava.** This is thrust aside from its neighbour of the opposite side by the opening up of the medulla to form the floor of the fourth ventricle, and the central canal of the cord opens on the surface in the angle between the two clavæ. The bulbous end of the fasciculus cuneatus receives the name of the **cuneate tubercle** (tuberculum cinereum), but it is only in the fœtal or very young brain that it is well marked.

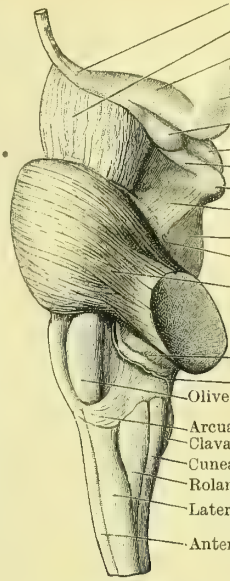


FIG. 335.—LATERAL VIEW OF THE MEDULLA, PONS, AND MESENCEPHALON OF A FULL-TIME HUMAN FŒTUS.

The elongated prominences formed on the surface of the medulla by these two strands and their enlarged extremities are, in a great measure, due to the presence of two elongated nuclei or collections of gray matter which make their appearance subjacent to the strands, and which gradually increase in bulk as they are traced upwards. These are termed respectively the **gracile** (nucleus funiculi gracilis) and **cuneate** (nucleus funiculi cuneati) **nuclei**, and it can be easily shown that as the gray matter increases in quantity the fibres of the two corresponding strands diminish in number by coming to an end in connexion with the cells of the subjacent nuclei. Indeed, it is doubtful if any of the fibres of the gracile and cuneate strands extend upwards beyond these nuclei.

But a third longitudinal elevation is also apparent in the lower part of the posterior area of the medulla. This is placed on the outer side of the funiculus cuneatus—between it and the posterior row of nerve-roots—and it has no counterpart in the posterior column of the cord. It is called the **funiculus of Rolando,** because it is produced by the substantia gelatinosa Rolandi, which caps the posterior horn, coming close to the surface and forming a bulging in this situation. The funiculus of Rolando is wedge-shaped in outline. Extremely narrow below, it widens as it is traced upwards, and finally ends in an expanded extremity called the **tubercle of Rolando** (tuberculum Rolandi). A thin layer of white matter, composed of longitudinally arranged fibres, is spread over this district, and separates the substantia Rolandi from the surface. These fibres constitute the spinal root of the fifth or trigeminal nerve, which here assumes a superficial position as it descends in the medulla.

The **restiform body** (corpus restiforme) forms the upper part of the posterior area of the medulla. It lies between the floor of the fourth ventricle and the roots of the vagus and glosso-pharyngeal nerves. It is a large and prominent rope-like strand, which inclines upwards and outwards, and then finally takes a turn backwards and enters the cerebellum. It forms the great link of connexion between the cerebellum on the one hand and the medulla and spinal cord on the other, and consequently it also receives the name of the **inferior cerebellar peduncle.** At the same time it must be understood that it is not formed by fibres which are prolonged into it from the funiculus cuneatus and funiculus

gracilis of the cord. It is true that a surface inspection of the medulla might very naturally lead the observer to this supposition, because there is no sharp line of demarcation marking it off from the tubercles of these strands. Such a conclusion, however, would be altogether erroneous, because it is questionable if any of the fibres of the posterior columns of the cord are carried beyond the gracile and cuneate nuclei of the medulla. A study of the surface of the medulla yields some important information regarding the constitution of the restiform body. Thus the direct cerebellar tract from the lateral column of the cord can be traced into it, and large numbers of fibres which take a curved course on the surface of the medulla may likewise be followed into it. These are the superficial arcuate fibres. Numerous other fibres enter the restiform body on its deep aspect, but these will be studied at a later stage.

Superficial Arcuate Fibres (fibræ arcuatæ externæ).—These fibres enter into the constitution of the restiform body, and they may be regarded as consisting of two sets, viz. the anterior superficial arcuate fibres and the posterior superficial arcuate fibres, both of which present this feature in common that they run on the surface of the medulla.

The **anterior superficial arcuate fibres** are more particularly seen in the neighbourhood of the olive, round the lower border of which, and also over the surface of which, they may be observed coursing in the form of a number of coarse curved bundles. They vary greatly in number and in distinctness, and they are sometimes so numerous as to cover over almost entirely the olivary eminence. An attentive examination will show that they come to the surface in the antero-median fissure between the pyramids, and also not unfrequently in the groove between the pyramid and olive, or through the substance of the pyramid itself. The antero-median fissure in its upper part is often almost completely blocked up by these emerging fibres. The anterior superficial arcuate fibres reaching the surface of the medulla in this manner turn backwards, and the great majority enter the restiform body and form a considerable part of its outer portion.

The **posterior superficial arcuate fibres** arise in the cuneate and gracile nuclei, and enter the restiform body of the same side.

THE PONS VAROLII.

The **pons Varolii** is a marked white prominence on the basal aspect of the brain which is interposed between the medulla and the crura cerebri, and which lies in front of the cerebellum. It is convex from side to side, as well as from above downwards, and transverse streaks on its surface show that, superficially at least, it is composed of bundles of nerve-fibres which course transversely over it. On either side these transverse fibres are collected together in the form of a large compact strand, which sinks in a backward and outward direction into the white matter of the corresponding hemisphere of the cerebellum. This strand is termed the **middle peduncle of the cerebellum**, and the term "pons," applied to the entire structure, expresses in an admirable way the arch-like manner in which this portion of the brain bridges across between the two cerebellar hemispheres.

The ventral surface of the pons is in relation to the basilar process of the occipital bone and the dorsum sellæ of the sphenoid bone. It presents a mesial groove (sulcus basilaris), which gradually widens as it is traced upwards, and in which the basilar artery lies. This mesial depression is produced by the prominence which is caused on either side by the passage of the pyramidal tract of the medulla upwards through the pons. The **trigeminal** or fifth cranial nerve, with its large entering sensory root and its small emerging motor root, is attached to the side of the ventral aspect of the pons, nearer its upper than its lower border. It is usual to restrict the term "pons" to that portion of the structure which lies between the two trigeminal nerves, and to apply the designation of middle cerebellar peduncle to the part which extends beyond the nerve into the hemisphere of the cerebellum. The sixth or **abducent nerve**, the seventh or **facial nerve**, and the eighth or **auditory nerve** are attached to the brain at the lower border of the pons. The sixth emerges at the outer border of the pyramid, the seventh immediately in front of the resti-

form body, whilst the auditory nerve reaches the brain close to the facial nerve, on the ventral aspect of the restiform body.

The whole of the medulla enters the lower aspect of the pons, and, with the exception of the restiform bodies, its constituent parts are, to a large extent, carried up within it. The crura cerebri emerge from its upper aspect.

The dorsal surface of the pons is turned backwards towards the cerebellum, and presents a triangular area covered with gray matter, which forms the upper part of the anterior wall or floor of the fourth ventricle. This area is directly continuous below with the medullary part of the floor of the fourth ventricle, and is bounded on either side by a band of white matter termed the **superior peduncle of the cerebellum.**

The **superior cerebellar peduncles** (brachia conjunctiva) are hidden from view by the upper part of the cerebellum, under cover of which they lie. They emerge from the lateral hemispheres of the cerebellum, and, as they proceed upwards on the dorsal aspect of the pons, they converge towards each other until, at the level of the inferior corpora quadrigemina, the inner margins of the two peduncles almost become contiguous (Fig. 333, p. 447). At first they form the lateral boundaries of the upper part of the fourth ventricle; but, as they ascend and approach closer to each other, they gradually come to overhang that cavity and thus enter into the formation of its roof. They disappear from the surface by dipping under cover of the quadrigeminal bodies and entering the substance of the mesencephalon.

Valve of Vieussens or the Superior Medullary Velum (velum medullare anterius).—Filling up the triangular interval between the two superior cerebellar peduncles, and stretching across from the inner and free margin of the one to the corresponding margin of the other, is a thin layer of white matter which completes the roof or dorsal wall of the upper part of the fourth ventricle, and receives the name of the superior medullary velum. When traced downwards, it is seen to be carried with the superior peduncles into the white matter of the cerebellum. Spread out on its dorsal surface is a small, thin, tongue-shaped prolongation of gray matter from the cortex of the cerebellum, which is termed the **lingula**, whilst issuing from its substance close to the inferior quadrigeminal bodies are the two **fourth** or **trochlear cranial nerves.**

Fourth Ventricle of the Brain (ventriculus quartus).—The fourth ventricle is somewhat rhomboidal in form. Below, it tapers to a point and becomes continuous with the central canal of the cord; above, it narrows in a similar manner and is continued into the aqueduct of Sylvius, which tunnels the mesencephalon. The posterior wall is termed the **roof** and is concealed by the cerebellum. The anterior wall is called the **floor** and is formed by the dorsal surface of the medulla and pons. On either side a narrow-pointed prolongation of the ventricular cavity is carried outwards from its widest part and curves round the upper part of the corresponding restiform body. This is termed the **lateral recess.** The roof of the cavity is very thin and intimately connected with the cerebellum. It is better, therefore, to defer its description until that part of the brain has been studied.

Floor of the Fourth Ventricle (fossa rhomboidea).—In its lower part the floor of the fourth ventricle is formed by the dorsal surface of the open part of the medulla, whilst in its upper part it is formed by the dorsal surface of the pons Varolii (Fig. 333, p. 447). The area thus constituted is lozenge-shaped, its widest part being opposite the middle peduncles of the cerebellum. A thick layer of gray matter, continuous with that which surrounds the central canal of the cord, is spread out like a carpet over the ventricular floor, and covering this is the usual ependymal layer, which lines all the ventricles of the brain. The area is circumscribed by definite lateral boundaries. Thus, *below* it is bounded on either side by the clava, the cuneate tubercle, and the restiform body; whilst *above* the lateral limits are formed by the superior cerebellar peduncles.

The floor of the fourth ventricle is divided into two lateral and symmetrical portions by a median groove. At the lower narrow end between the two clavæ it receives the name of the **calamus scriptorius**, from its fancied resemblance to the point of a pen. Crossing each half of the floor, at its widest part, are several trans-

verse bundles of fibres termed the **striæ acusticæ**. They appear to emerge from the mesial groove and they are carried outwards over the upper part of the restiform body. They somewhat resemble the superficial arcuate fibres on the lateral surface of the medulla, and their connexions will be discussed at a later stage. The striæ acusticæ divide each lateral half of the ventricular floor into upper and lower portions, which very nearly correspond to the subdivisions of this area formed by the medulla and the pons. Except for this break on the surface, the medullary and pontine portions of the floor of the fourth ventricle are quite continuous with each other.

On the lower medullary district of the ventricular floor a small triangular depression placed immediately below the striæ acusticæ catches the eye. This is termed the **fovea inferior**. It is shaped somewhat like an arrow-head. The apex or point looks towards the striæ, whilst the lateral angles of the base are prolonged downwards in the form of diverging grooves (Fig. 333, p. 447). Of these, the inner groove runs towards the opening of the central canal at the calamus scriptorius, whilst the outer groove runs towards the lateral boundary of the floor. In this manner the portion of the floor which lies below the striæ acusticæ is mapped out into three triangular areas. The mesial subdivision is slightly elevated and is termed the **trigonum hypoglossi**, because, subjacent to this area, is the nucleus of origin of the hypoglossal or twelfth cranial nerve. The intermediate area between the two diverging grooves which proceed from the base of the fovea inferior is the **trigonum vagi** (ala cinerea), so called because the terminal nucleus of the vagus or tenth and the glosso-pharyngeal or ninth cranial nerves lies subjacent to it. The external area is the **trigonum acustici.** The base of this area is directed upwards and runs continuously into an eminence—the **acustic area** (area acustica)—over which the striæ acusticæ pass. Subjacent to this district of the floor of the ventricle lies the large terminal chief nucleus of the vestibular division of the auditory or eighth cranial nerve.

On the part of the floor of the ventricle which lies above the striæ acusticæ, and which corresponds to the dorsal surface of the pons, there is also a slight depression termed the **fovea superior**. Between it and the median groove is a marked prominence called the **eminentia teres**. Inferiorly this elevation passes downwards and becomes continuous with the trigonum hypoglossi, whilst above it is carried upwards towards the opening of the aqueduct of Sylvius. In both directions it becomes gradually less prominent, but still it forms a distinct elongated elevation, which stretches along the whole length of the median groove. As already stated, the **area acustica** extends upwards into the pontine part of the ventricular floor and forms an elevated region in the outermost part of its widest portion, below and to the outer side of the fovea superior. Proceeding upwards from the fovea superior to the opening of the Sylvian aqueduct there is a shallow depression termed the **locus cæruleus**, seeing that it usually presents a faint slate gray colour. When the ependyma is scraped away from the surface of this part of the floor, the colour is seen to be due to the **substantia ferruginea**,—a name applied to a linear group of strongly pigmented cells, which lies in the lateral part of the gray matter covering this portion of the ventricular floor. When transverse sections are made through the upper part of the pons, the substantia ferruginea appears on the cut surface as a small black spot.

INTERNAL STRUCTURE OF THE MEDULLA.

The internal structure of the medulla differs in a marked degree from that of the spinal cord; indeed, in its upper part it presents very little in common with the latter. The various strands of the cord either come to an end within the medulla or undergo changes in their relative position, whilst the gray matter is much modified and new masses are added. Like the cord, however, the medulla consists of two nearly symmetrical right and left halves. When transverse sections are made through it at different levels each lateral half is seen to be partly marked off from the other in the lower closed part of the medulla by the anterior and posterior median fissures, whilst in the upper open part of the medulla the subdivision is

rendered evident in transverse sections by the presence of a distinct median line, called the **raphe**, which occupies the mesial plane. The raphe is formed by the close intersection of fibres running in different directions and crossing from one side to the other.

Each half of the medulla is composed of: (*a*) strands of white matter; (*b*) gray matter; and (*c*) the formatio reticularis.

The **white matter**, as in the cord, is to a large extent disposed on the surface, and the gray matter in the interior; but in the upper open part of the medulla the gray matter comes to the surface on the dorsal aspect, and is spread out over that area which forms the medullary part of the floor of the fourth ventricle. In the cord the white matter, in the shape of massive longitudinal strands of fibres, forms a thick coating round the central gray matter. In the medulla the only massive longitudinal strands which are seen on the surface are the gracile and cuneate strands (until they become absorbed by the subjacent nuclei), the inferior cerebellar peduncles or restiform bodies and the pyramidal tracts. Elsewhere the coating of white matter is thin, and in certain places is composed chiefly of the superficial arcuate fibres. New longitudinal strands, however, take shape within the medulla, and two of the most important are placed on either side of the median raphe.

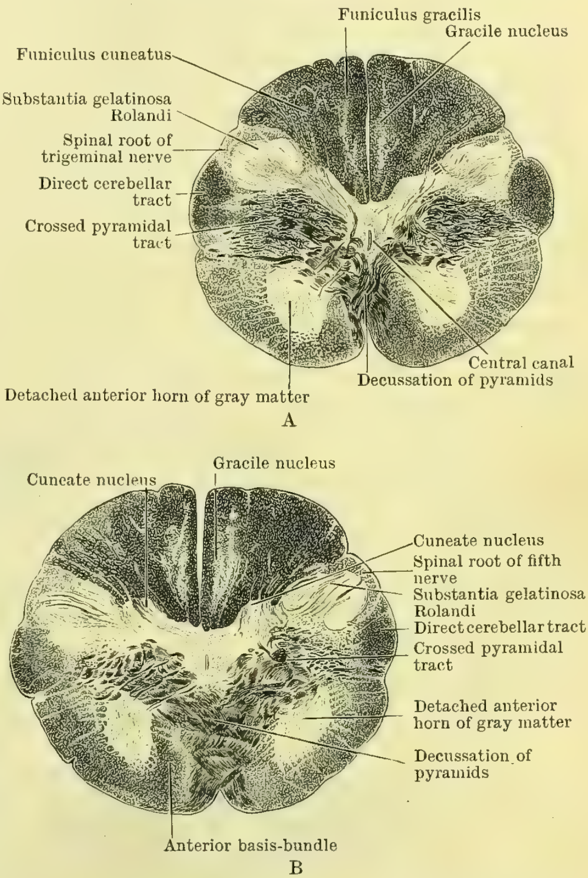


FIG. 336.—TWO SECTIONS THROUGH THE JUNCTION BETWEEN THE CORD AND MEDULLA OF THE ORANG. A at a slightly lower level than B.

The **gray matter** of the cord, as it is continued upwards into the medulla, becomes greatly modified. A considerable part of it is broken up in the formatio reticularis, whilst the only portions which remain as compact masses in direct continuity with the gray matter of the cord are: (1) the thick layer which surrounds the central canal, and which, in the open part of the medulla, becomes spread out on the floor of the fourth ventricle; and (2) the substantia gelatinosa Rolandi. New masses of gray matter, which are not represented in the cord, and which in some cases appear in isolated clumps, are also added. The chief of these are the gracile and cuneate nuclei, the olivary nuclei, and the arcuate or pyramidal nuclei.

The **formatio reticularis** is only feebly represented in the cord, but in the medulla it forms a very considerable part of its bulk. It is composed of gray matter coarsely broken up by fibres, which traverse it in different directions.

In the following detailed account of the internal structure of the medulla, it must be understood that the appearances described are such as are seen when successive transverse sections through the bulb are examined.

Decussation of the Pyramids and the Changes produced thereby.—As we pass under the microscope a series of successive transverse sections through the upper end of the cord and the lower end of the medulla, the most striking change which meets the eye is the decussation of the pyramids. The crossed pyramidal

tract in the lateral column of the cord is seen to become looser in its formation; then coarse strands leave it, pass right through the anterior horn of gray matter, and, crossing the mesial plane, take up their position in the other side of the medulla, close to the antero-median fissure. Strands from the right crossed pyramidal tract alternate with corresponding strands from the left side, and the interval between the bottom of the antero-median furrow and the gray matter surrounding the central canal becomes filled up with a great mass of intercrossing bundles of fibres. When the decussation is completed the pyramid is seen to be composed of a solid and compact bundle of fibres, well marked off from the surrounding structures, which lies at the side of the antero-median fissure of the medulla.

As a rule the inner three-fourths of the pyramid is composed of fibres which, lower down in the opposite lateral column of the cord, form the crossed pyramidal tract, whilst the outer fourth of the pyramid proceeds downwards in the anterior column of the cord of the same side as the direct pyramidal tract. A considerable amount of variation, however, occurs in the proportion of fibres which is allotted to the formation of these two tracts of the cord. Sometimes the crossed pyramidal tract is much larger than usual, and then the direct pyramidal tract suffers a corresponding diminution in size. Cases indeed occur in which the entire pyramid enters into the decussation, and in these there is no direct pyramidal tract in the cord. Further, it is not uncommon to meet with variations of an opposite kind which lead to an increase of the direct pyramidal tract at the expense of the crossed tract. In the majority of cases the decussation appears to be symmetrical—the division of the pyramid at the lower end of the medulla being into parts of corresponding size on the two sides; in certain instances, however, the decussation is asymmetrical, and the corresponding pyramidal tracts on opposite sides of the cord are then unequal in size. Seeing that the direct pyramidal tracts undergo a gradual decussation in the anterior commissure, as they descend in the cord, the final result is the same, no matter what variations occur in the decussation at the lower part of the medulla.

The variations indicated above receive an additional interest when viewed in the light of comparative anatomy. It would appear that only in man and the anthropoid apes is the decussation of the pyramids in the lower part of the medulla incomplete. According to Sherrington, a direct pyramidal tract in the cord of the anthropoid apes stands in connexion with the arm-centre in the cerebral cortex. In the lower apes a direct pyramidal tract does not seem to exist: the whole pyramid crosses over to the opposite side of the cord in the shape of the crossed pyramidal tract.

As we have noted, the decussating pyramidal bundles pass through the anterior horn of gray matter of the cord, and cut it into two portions (Fig. 336, B). The basal part remains in position on the anterior and lateral aspect of the central canal, and forms part of the thick layer of gray matter which surrounds it. The detached head of the anterior horn is set free; and from the large multipolar cells which lie in its midst some of the fibres of the anterior root of the first cervical nerve, and also some of the root fibres of the spinal accessory nerve, take origin.

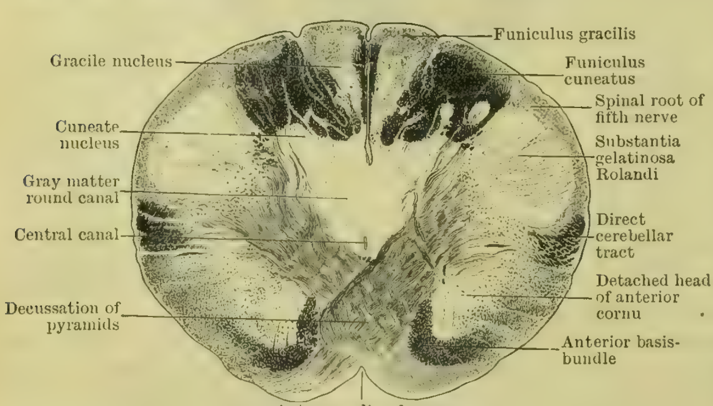


Fig. 337.—Transverse Section through Lower End of the Medulla of a Full-time Fœtus,

Treated by the Pal-Weigert method. The gray matter is bleached white, and the medullated tracts of fibres are black.

On proceeding up into the medulla another effect of the decussation of the pyramids is seen in the submergence from the surface of the strand of fibres which, in the anterior column of the cord, lies to the outer side of the direct pyramidal

tract, and which receives the name of the anterior basis-bundle. While the decussation is going on the anterior basis-bundle is thrust aside, and, sinking from the surface, it takes up its position as a flattened band-like strand on the outer side of the gradually increasing pyramid (Fig. 337). When the decussation is completed this strand is seen to lie close to the median plane on the dorsal aspect of the pyramid, where it is separated from its fellow of the opposite side by the median raphe alone (Fig. 338). In the upper part of the medulla it approaches still nearer to the dorsal surface and appears to form the greater part of a strand, which is termed the **posterior longitudinal bundle** (Figs. 340 and 341). The detached head of the anterior horn of gray matter of the cord, as it is traced upwards, is observed to cling closely to its original relationship with the anterior basis-bundle. It is applied to the outer side of this strand, and, gradually becoming smaller, finally disappears at the level of the lower part of the inferior olivary nucleus.

Cuneate and Gracile Strands, with their Nuclei.—As the funiculus gracilis and the funiculus cuneatus of the posterior column of the cord are traced up into the medulla they seem to increase in bulk, and in transverse sections they assume the form of massive wedge-shaped strands, quite distinct from each other. When the decussation of the pyramids is fully established they change their shape. They increase in width and lose considerably in depth, and consequently the transverse diameter of the area which they occupy becomes greater. As a result of this, they push outwards the posterior horn of gray matter to such a degree that very soon it comes to lie transversely and in the same straight line with its fellow of the opposite side (Figs. 336 and 337). The substantia gelatinosa

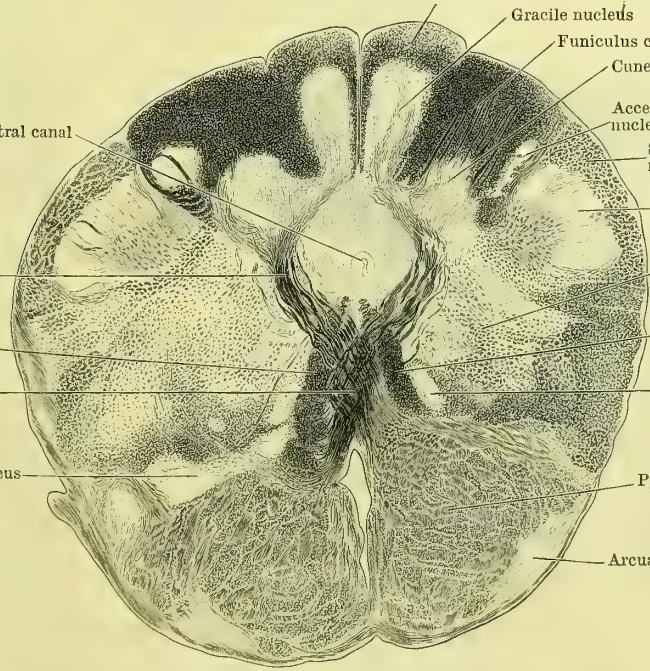


FIG. 338.—SECTION THROUGH THE CLOSED PART OF HUMAN MEDULLA IMMEDIATELY ABOVE THE DECUSSATION OF THE PYRAMIDS.

Rolandi, at the same time, becomes increased in quantity and presents a horseshoe-shaped outline in transverse section. It clasps within its concavity the somewhat reduced head of the posterior horn, and forms with it a conspicuous circular mass of gray matter which lies close to the surface, and produces upon it the bulging termed the funiculus and tubercle of Rolando. The basal portion of the posterior horn of gray matter remains upon the dorsal and lateral aspect of the central canal, and forms a portion of the central gray mass of the closed part of the medulla; but very soon the neck of the horn is invaded by bundles of fibres

which traverse it in different directions and convert it into a formatio reticularis. By this means the rounded head of the posterior horn becomes cut off from the central gray matter, and from this point upwards it remains as an isolated gray column intimately associated with the spinal root of the trigeminal nerve.

The **gracile** and **cuneate nuclei** take shape before the decussation of the pyramids is fully completed (Fig. 336). The **gracile nucleus** appears in the form of a small irregular mass of gray matter in the interior of the funiculus gracilis, which gradually infiltrates the entire strand. At first it is not directly connected with the gray matter which surrounds the central canal; but as it is traced upwards it increases in bulk, absorbs more of the strand in which it lies, and such a connexion becomes established (Figs. 337 and 338).

The **cuneate nucleus**, from the first, is a direct offshoot from that part of the base of the posterior horn of gray matter which is preserved as a portion of the central gray mass. In transverse section it is seen to invade the funiculus cuneatus upon its deep aspect, and it gradually grows backwards into its substance. It presents a very different appearance from the gracile nucleus, because throughout its whole length the gray nucleus and the fibres of the strand are separated from each other by a sharp line of demarcation. A second and much smaller mass of gray matter appears in the funiculus cuneatus, superficial to the main nucleus, soon after the region of the decussation of the pyramids is left. This is termed the **accessory** or the **external cuneate nucleus** (Fig. 338).

Gradually the fibres of the gracile and cuneate strands become absorbed in these nuclei. As the gray masses gain in size a corresponding diminution in the number of fibres composing the corresponding tracts is observed until, at the level of the clava and cuneate tubercles, it is seen that these eminences are composed almost entirely of the gray nuclei, covered by a thin skin of the few remaining fibres of the two strands involved. It is extremely doubtful if any fibres belonging to the funiculus gracilis and funiculus cuneatus get beyond these nuclei. They apparently all end in fine terminal ramifications around the cells of the nuclei. In the case of the funiculus cuneatus the bundles of fibres, as they pass from the surface into the subjacent gray nucleus, are very distinctly seen in transverse sections through the medulla.

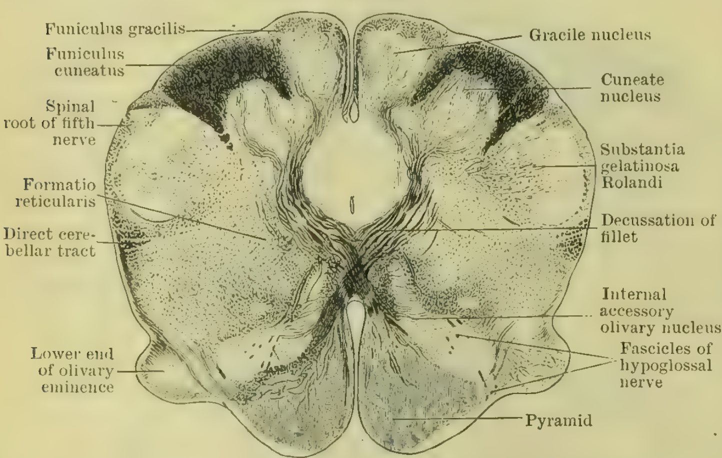


FIG. 339.—TRANSVERSE SECTION THROUGH THE CLOSED PART OF A FŒTAL MEDULLA, IMMEDIATELY ABOVE THE DECUSSATION OF THE PYRAMIDS. Treated by Pal-Weigert method.

When the medulla oblongata opens up into the fourth ventricle the gracile and cuneate nuclei are pushed outwards by the expanding ventricular floor, and the gracile nucleus soon comes to an end; but the cuneate nucleus extends upwards for a short distance further, and only terminates when the restiform body begins to take definite shape on its outer aspect.

Decussation of the Fillet (decussatio lemniscorum).—Immediately above the level of the decussation of the pyramids another decussation of fibres in the median plane, and upon the dorsal aspect of the pyramids, takes place in the substance of the medulla. This is termed the **decussation of the fillet**, or the **sensory decussation**, in contradistinction to the term "motor decussation," which is sometimes applied to the decussation of the pyramids. The fibres which take part in this decussation

are called **deep arcuate fibres** (fibræ arcuatæ internæ), and they are derived from the cells of the gracile and cuneate nuclei. From the deep aspects of these nuclei these fibres stream forwards and inwards towards the median raphe, forming a series of concentric curves in the substance of the medulla. They cross the mesial plane and decussate with the corresponding fibres of the opposite side, upon the dorsal aspect of the pyramids. Having thus gained the opposite side of the medulla they immediately turn upwards and form a conspicuous strand of longitudinal fibres, which ascends close to the mesial plane and is separated from its fellow of the opposite side by the medial raphe alone. This strand is termed the **fillet** or **lemniscus**.

As we proceed up the medulla the deep arcuate fibres which first come into sight appear as coarse bundles which curve forwards in a narrow group around the central gray matter. Soon other finer bundles appear, which describe wider curves on the outer side of the coarser group until a very large part of each lateral half of the medulla is seen to be traversed by these arcuate fasciculi. As they approach the mesial plane they come in contact with the remains of the anterior basis-bundle, which at this level, as already mentioned, lies upon the dorsal aspect of the pyramid, flattened up against the raphe. The deep arcuate fibres pierce the anterior basis-bundle obliquely, and in the interval between it and the corresponding strand of the opposite side they decussate in the middle line with the deep arcuate fibres of the opposite side. They then change their direction and turn upwards, and the fillet, as already stated, takes form and gradually increases in volume as it ascends. This great and important tract is thus laid down between the pyramid and the anterior basis-bundle; and the consequence of this is that the latter tract is pushed still further backwards, and when the fillet is fully established it comes to lie immediately beneath the gray matter of the floor of the fourth ventricle (Fig. 341).

When the fillet is fully formed three longitudinal strands are observed traversing the medulla, close to the mesial plane. From before backwards these are: (1) the pyramid, (2) the fillet, and (3) the posterior longitudinal bundle. The pyramid forms a massive tract quite distinct from the fillet, which lies behind it. The fillet and the posterior longitudinal bundle are, in the first instance, not marked off from each other. They appear as a broad flattened band applied to the raphe. One edge of this band is directed backwards and reaches the gray matter on the floor of the fourth ventricle, while the other edge looks forwards, and is in contact with the pyramid. In the upper part of the medulla the fillet and the posterior longitudinal fasciculus begin to draw asunder from each other. The intermediate longitudinal fibres become reduced in number and the two strands grow denser—the one on the dorsal aspect of pyramid, and the other immediately beneath the gray matter of the floor of the fourth ventricle (Fig. 341).

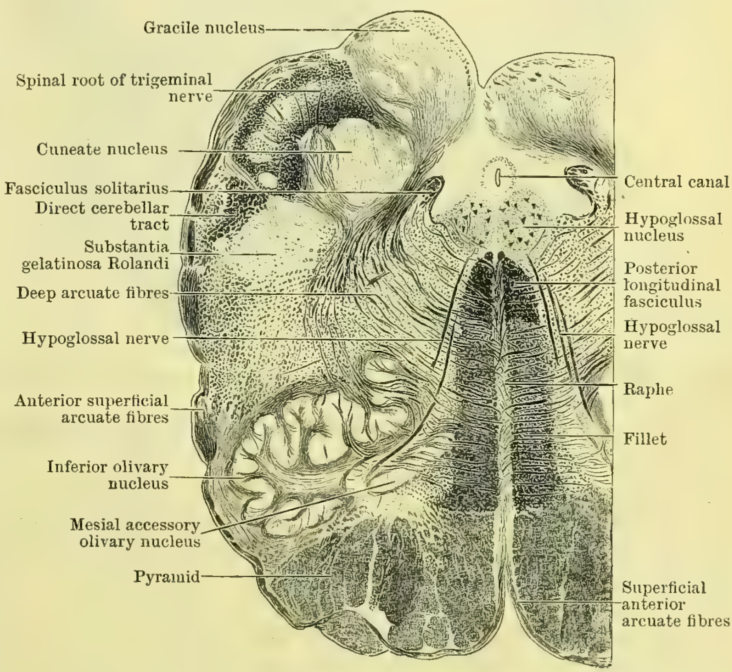


FIG. 340.—TRANSVERSE SECTION THROUGH THE HUMAN MEDULLA IN THE LOWER OLIVARY REGION.

The **posterior longitudinal bundle** (fasciculus longitudinalis medialis) is thus largely formed out of fibres, which in the cord constitute the anterior basis-bundle. These fibres are thrust back by the two decussations: the first decussation pushing them behind the pyramids, and the second decussation displacing them still further backwards to a position behind the fillet.

Olivary Nuclei.—The most conspicuous of the isolated clumps of gray matter in the medulla are the inferior olivary nucleus and the two accessory olivary nuclei. The **inferior olivary nucleus** (nucleus olivaris inferior) lies subjacent to the olivary eminence, and constitutes a very striking object in transverse sections through this region. It presents the appearance of a thick wavy or undulating line of gray matter, folded on itself, so as to enclose a space filled with white matter. It is in reality a crumpled lamina arranged in a purse-like manner, with an open mouth or slit, which is called the **hilum** (hilum nuclei olivaris), directed towards the

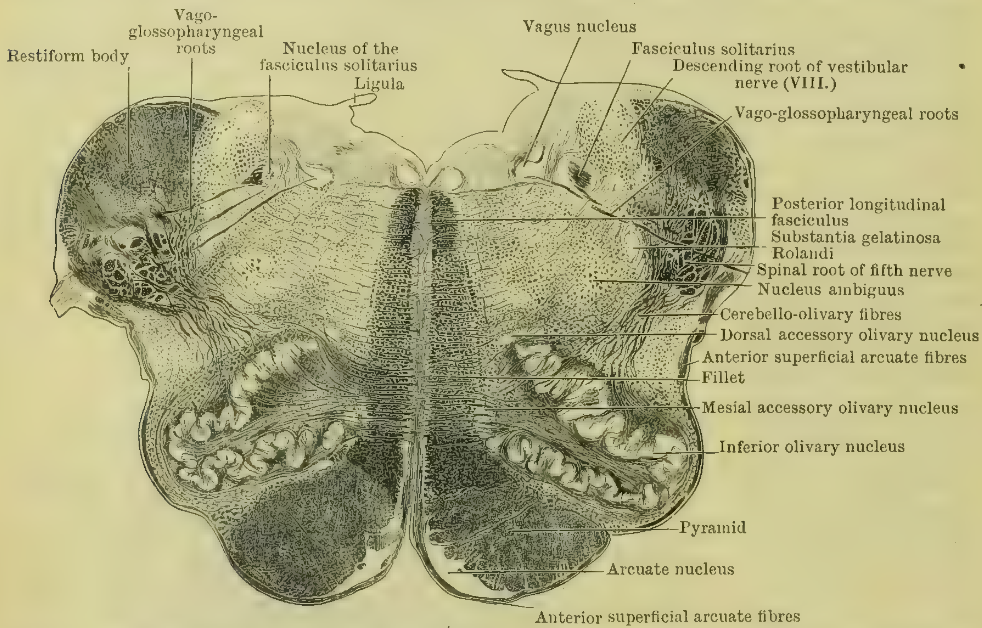


FIG. 341.—TRANSVERSE SECTION THROUGH THE MIDDLE OF THE OLIVARY REGION OF THE HUMAN MEDULLA OR BULB.

The floor of the fourth ventricle is seen, and it will be noticed that the restiform body on each side has now taken definite shape.

mesial plane. The hilum does not reach either extremity, so that in transverse sections through each end of the nucleus the gray lamina is seen in the form of a completely closed capsule. Into and out of the open mouth of the olivary capsule streams a dense crowd of fibres. These constitute what is called the **olivary peduncle.**

The **accessory olivary nuclei** are two band-like laminæ of gray matter, which are respectively placed on the dorsal and mesial aspects of the main nucleus. In transverse section each of these nuclei presents a rod-like appearance.

The **mesial accessory olivary nucleus** (nucleus olivaris accessorius mesialis) extends lower down in the medulla than the main nucleus, and it is much larger in its lower than its upper part. It begins immediately above the decussation of the pyramids, where it is seen lying immediately on the outer side of the pyramidal tract and the anterior basis-bundle (Fig. 338). Higher up it lies across the mouth of the main nucleus and on the outer side of the fillet. The **dorsal accessory olivary nucleus** (nucleus olivaris accessorius dorsalis) is placed close to the dorsal aspect of the main nucleus. It begins at the level at which the main olive first presents a hilum, and it comes to an end at the level at which the central canal opens into the fourth ventricle. The two accessory nuclei fuse together before they finally disappear.

The gray matter forming the three inferior olivary nuclei is crowded with small round cells, each of which is provided with one axon and numerous dendrites. It is traversed

by fibres, some of which pass straight through the gray lamina, whilst others end in connexion with the cells. It is only in mammals that the olivary nuclei are found well developed.

As the fibres of the fillet decussate and assume a longitudinal direction they come to lie between the olivary nuclei of opposite sides, and hence the term **inter-olivary stratum** (stratum interolivare lemnisci) is frequently applied to them.

Restiform Body (corpus restiforme).—The gracile and cuneate nuclei gradually give place to the restiform body in the upper part of the posterior district of the medulla. Fibres from various quarters converge to form this great strand. It first takes shape as a thin superficial layer of longitudinal fibres, which are gathered together on the outside of the cuneate nucleus; but after that nucleus has come to an end, and as the upper part of the medulla is reached, the restiform body is seen to have grown into a massive strand, which presents a kidney-shaped or oval outline on transverse section (Fig. 341), and which ultimately enters the white central core of the cerebellum as its inferior peduncle. The fibres which build up the restiform body are the following: (1) the direct cerebellar tract; (2) the posterior superficial arcuate fibres; (3) the anterior superficial arcuate fibres; and (4) cerebello-olivary fibres.

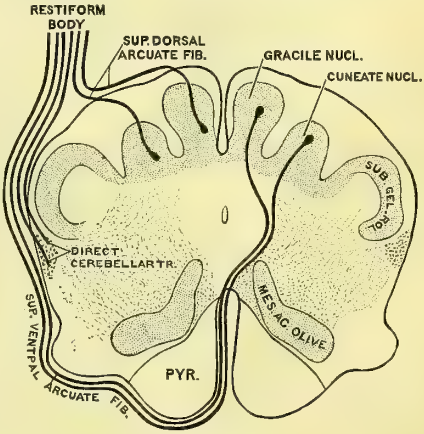


FIG. 342.—DIAGRAM,

Which shows in part the fibres which enter into the constitution of the restiform body.

The **direct cerebellar tract** extends upwards from the lateral column of the cord. In the lateral district of the medulla it occupies a similar position; but before the olivary eminence is reached it inclines backwards, crosses the postero-lateral furrow, and passes obliquely upwards into the restiform body. As its fibres diverge backwards they pass over the tubercle of Rolando and cover up the spinal root of the trigeminal nerve and the substantia Rolandi, thus shutting them out from the surface. The fibres of the direct cerebellar tract enter into the outer or superficial part of the restiform body.

The **posterior superficial arcuate fibres** take origin from the gracile and cuneate nuclei, and enter the superficial part of the restiform body of the same side.

The **anterior superficial arcuate fibres** proceed from the lower portions of the gracile and cuneate nuclei of the opposite side. After decussating in the middle line, it can easily be determined that all the deep arcuate fibres which arise from these nuclei do not enter the fillet. A large proportion of them gain the surface by sweeping round the inner aspect of the pyramid in the antero-mesial fissure. Many of them likewise gain the surface by piercing the pyramid or by passing out between it and the olive. These fibres constitute the anterior superficial arcuate group, and on the surface of the medulla they sweep backwards around it, forming a thin layer over the olivary eminence and ultimately reaching the restiform body. The anterior superficial arcuate fibres, as well as the direct cerebellar tract-fibres, cover over the trigeminal spinal root, which thus comes to take up a deeper position in the substance of the medulla (Figs. 340 and 341).

Amongst the fibres which reach the surface of the medulla in this way Kölliker includes fibres from the striæ acusticæ. If this be the case, these fibres connect the cochlear nucleus with the cerebellum, the path being striæ acusticæ, superficial arcuate fibres, and restiform body (*vide* p. 481).

The fibres of the direct cerebellar tract, which come from the cells of the posterior vesicular column of the cord, and the superficial posterior arcuate fibres, which are derived from the cells of the gracile and cuneate nuclei, do not cross the mesial plane, but enter the restiform body of the same side. The anterior superficial arcuate fibres arise from the cells of the cuneate and gracile nuclei, and cross the mesial plane so as to gain the restiform body of the opposite side.

The **cerebello-olivary fibres** are only seen in the upper part of the medulla. They

form the deep part of the restiform body and constitute its chief bulk. Streaming out from the hilum of the inferior olivary nucleus, they cross the mesial plane, and on the opposite side of the medulla they either pass through the inferior olivary nucleus of that side or sweep around it. Ultimately, on the dorsal aspect of the olivary nucleus, they are gathered together in the form of a conspicuous group of arcuate fibres, which curve backwards to take up a position in the deep part of the restiform body. In passing back, they traverse the spinal root of the trigeminal

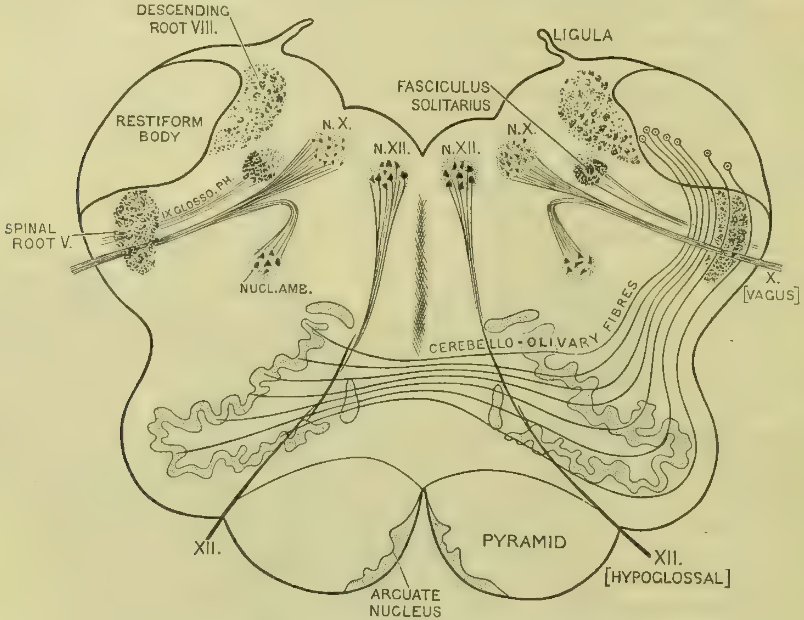


FIG. 343.—DIAGRAM OF THE CEREBELLO-OLIVARY FIBRES.
(This diagram has been constructed from the specimen figured on page 458.)
N.X., Vago-glossopharyngeal nucleus. N.XII., Hypoglossal nucleus.

nerve and break it up into several separate bundles. The cerebello-olivary fibres thus connect the inferior olivary nucleus of one side with the opposite side of the cerebellum.

Although we have traced the cerebello-olivary fibres in an upward direction from the olive to the cerebellum, it is right to state that in all probability it is the great efferent tract of the inferior cerebellar peduncle. Its fibres are believed to arise in the cortex of the cerebellum (probably as the axons of the cells of Purkinje) and to descend in the inferior peduncle to establish connexions with the cells of the olivary nucleus of the opposite side. The destination of the axons of the cells of the inferior olivary nucleus is not known with certainty, but Kölliker considers that they enter the lateral column of the cord. Whilst this may be regarded as the generally accepted view of the cerebello-olivary fibres, it is right to mention that Klimoff, in his recent work on the cerebellum, maintains that they are afferent in their function, and not efferent.

Arcuate Nucleus (nucleus arcuatus).—Immediately above the decussation of the pyramids, a small flattened mass of gray matter, covered by superficial arcuate fibres, makes its appearance on the ventral or superficial aspect of the pyramid (Fig. 338). At a higher level, when the open part of the medulla is reached, this gray mass shifts its position and comes to lie upon the mesial aspect of the pyramid, and thus constitutes the immediate boundary of the antero-median fissure (Fig. 341). From its intimate connexion with the anterior superficial arcuate fibres, as they sweep out from the antero-median fissure, it receives the name of the **arcuate nucleus.**

The nerve-cells which lie in its midst are smaller than those of the inferior olivary nucleus, and are fusiform in shape. It would appear that large numbers of the anterior superficial arcuate fibres end in this nucleus, whilst others take origin within it. Many of the anterior arcuate fibres, however, sweep continuously over its surface and bind it down to the pyramid. At the upper end of the medulla the arcuate nucleus increases in size, and ultimately it becomes continuous with the gray matter of the ventral part of the pons.

Formatio Reticularis.—Behind the olive and the pyramid is the formatio reticularis. In the medulla it occupies a position which, to a large extent, corresponds with that of the lateral column in the spinal cord. In transverse section it appears as an extensive area, which is divided into a lateral and a mesial field by the root fascicles of the hypoglossal nerve as they traverse the substance of the medulla to reach the surface. In the lateral portion which lies behind the olive there is a considerable quantity of gray matter, continuous with that in the cord, present in the reticular formation; it is, therefore, called the **formatio reticularis grisea.** In the mesial part which lies behind the pyramid the gray matter is extremely scanty, and the reticular matter here is termed the **formatio reticularis alba.**

In the **formatio grisea** the cells which are scattered thickly amongst the intersecting bundles of fibres correspond to the strand-cells of the cord. They possess short axons, which serve to bind different levels of the medulla to each other. They therefore constitute association fibres. Certain compact masses of gray matter are also seen in the formatio grisea. Of these may be mentioned (*a*) the dorsal accessory olivary nucleus, which has been already described, and (*b*) the nucleus lateralis. The **nucleus lateralis** is seen in the region between the olive and the substantia gelatinosa Rolandi. In the upper part of the medulla it gradually becomes diffuse and disappears.

Except in the immediate vicinity of the raphe, the **formatio alba** may be said to be devoid of cells. The mesial accessory olive, however, forms an isolated compact mass of gray matter within its limits.

The nerve fibres which traverse the formatio reticularis run both in a transverse and a longitudinal direction. The **transverse fibres** are the deep arcuate fibres. The **longitudinal fibres** are derived from different sources in the two fields. In the formatio grisea they represent to a large extent the fibres of the lateral column of the cord, after the removal of the direct cerebellar and the crossed pyramidal tracts. They consist, therefore, of the fibres of the tract of Gowers and of fibres corresponding to the lateral basis-bundle of the cord. In the formatio alba the longitudinal fibres are the tract of the fillet and the posterior longitudinal bundle, both of which have already been sufficiently described.

Central Canal and the Gray Matter which surrounds it.—The central canal, as it proceeds upwards through the closed part of the medulla, is gradually forced to assume a more dorsal position, owing to the accumulation of fibres on its ventral aspect. First the decussation of the pyramids, and then the decussation of the fillet, both of which take place in front of the canal, tend to push it backwards; and the formation of the longitudinal strands in which these intercrossings result (viz. the pyramid and the fillet), together with the continuation upwards of the anterior basis-bundle, lead to a great increase in the amount of tissue which separates it from the anterior surface of the medulla. In the closed part of the medulla it is surrounded by a thick layer of gray matter, which is continuous with the basal portions of the anterior and posterior horns of gray matter in the cord. This central gray matter is sharply defined on each side by the deep arcuate fibres which curve forwards and inwards around it. Finally, the central canal opens on the dorsal aspect of the medulla into the cavity of the fourth ventricle. The central mass of gray matter which surrounds the canal in the closed part of the medulla is now spread out in a thick layer on the floor of the fourth ventricle, and in such a manner that the portion which corresponds to the basal part of the anterior horn of the cord is situated close to the mesial plane, whilst the part which represents the base of the posterior horn occupies a more lateral position. This is important, because the nucleus or origin of the motor hypoglossal nerve is placed in the mesial part of the floor, whilst the nuclei of termination of the afferent fibres of the vagus, glosso-pharyngeal, and auditory nerves lie in the lateral part of the floor. The gray matter of the ventricular floor is covered by ependyma.

Three Areas of Flechsig.—In transverse sections, through the upper open part of the medulla, the root fibres of the hypoglossal and vagus nerves are seen traversing the substance of the medulla. The nucleus of origin of the hypoglossal is placed in the gray matter of the floor of the fourth ventricle close to the mesial plane; the nucleus of termination of the vagus is situated in the gray matter of the ventricular floor immediately to the outer side of the hypoglossal nucleus. From these nuclei the root-bundles of the two nerves diverge from each other

as they are traced to the surface and subdivide the substance of the medulla, as seen in transverse section, into the three areas of Flechsig, viz. an anterior, a lateral, and a posterior.

The **anterior area**, which is bounded internally by the median raphe and externally by the hypoglossal roots, presents within its limits: (*a*) the formatio alba; (*b*) the pyramid; (*c*) the fillet; (*d*) the posterior longitudinal fasciculus; (*e*) the mesial accessory olivary nucleus; (*f*) the arcuate nucleus.

The **lateral area** lies between the root fibres of the hypoglossal and those of the vagus. It contains: (*a*) the inferior olivary nucleus; (*b*) the dorsal accessory olivary nucleus; (*c*) the nucleus lateralis; (*d*) the nucleus ambiguus, or the motor nucleus of the vagus and glosso-pharyngeal nerves; (*e*) the formatio reticularis grisea.

The **posterior area** is situated behind the vagus roots, and within its limits are seen: (1) the restiform body; (2) the upper part of the cuneate nucleus; (3) to the inner side of this a crowd of transversely-cut bundles of fibres, loosely arranged and forming the descending root of the vestibular part of the auditory nerve; (4) close to these, but placed more deeply, a round, compact, and very conspicuous bundle of transversely-cut fibres, viz. the fasciculus solitarius, or descending root of the vagus and glosso-pharyngeal nerves; (5) the substantia gelatinosa Rolandi, much reduced, with the large spinal root of the trigeminal nerve close to its outer side.

INTERNAL STRUCTURE OF THE PONS VAROLII.

When transverse sections are made through the pons, it is seen to be composed of a ventral part and a dorsal or tegmental part. The **ventral part** is much the larger of the two, and, broadly speaking, it corresponds to the pyramidal portions of the medulla and the pedal portions of the two crura cerebri, which lie above it and appear to issue from it. The dorsal **tegmental part** may be regarded as the continuation upwards of the formatio reticularis grisea and the formatio reticularis alba. As these parts are traced upwards into the pons they become much modified, and new constituents are added.

Ventral Part of the Pons (pars basilaris pontis).—This constitutes the chief bulk of the pons. It is composed of: (1) transverse fibres arranged in coarse bundles; (2) longitudinal fibres, gathered together in massive bundles; and (3) a large amount of gray matter, termed the **nucleus pontis**, which fills up the interstices between the intersecting bundles of fibres.

The **longitudinal fibres**, to a large extent, consist of the same fibres which, lower down, are gathered together in the two solid pyramidal tracts of the medulla. When the pyramids are traced upwards they are seen to enter the pons in the form of two compact bundles. Soon, however, they become broken up into smaller bundles by the transverse fibres of the pons, and are spread out over a wider area. At the upper border of the pons they again come together and form two solid strands, each of which is carried into the central part of the corresponding pedal portion of the crus cerebri.

The **transverse fibres** at the lower border of the pons are placed on the superficial or ventral aspect of the pyramidal bundles. As we proceed upwards they increase in number, and many are seen breaking through the pyramids and even passing across upon the dorsal aspect of the latter. Laterally these transverse fibres are collected together into one compact mass, which enters the white central core of the cerebellum and constitutes the **middle cerebellar peduncle**. At the mesial plane the transverse fibres of the two sides of the ventral portion of the pons intercross and form a coarse decussation.

The **gray matter** (the nucleus pontis) forms a considerable part of the bulk of the ventral portion of the pons. It is packed into the intervals between the intersecting transverse and longitudinal bundles.

There is a close analogy between the pyramidal portions of the medulla and the ventral part of the pons. In the medulla fine arcuate fibres on their way to the surface pass through the pyramids. Other superficial arcuate fibres sweep over the surface of the pyramids. These present a strong resemblance to the transverse fibres of the pons. They likewise reach the cerebellum, although by a different route, viz. the inferior cerebellar peduncle. The nucleus pontis is also represented in the pyramidal part of the medulla by the arcuate nuclei, which are covered over by the superficial arcuate fibres and even tend to penetrate, to a slight extent, into the pyramidal tracts. These arcuate nuclei, as already pointed out, are continuous with the nucleus pontis.

Connexions of the Longitudinal and Transverse Fibres.—Our knowledge of the connexions of the longitudinal and transverse fibres of the ventral part of the pons is

very far from being complete. When a transverse section through the upper part of the pons is compared with one close to its lower border, it becomes at once apparent that the numerous scattered bundles of longitudinal fibres which enter the ventral part of the pons from above, if brought together into one tract, would form a strand very much larger than the two pyramids which leave its lower aspect and enter the medulla. It is clear, therefore, that many of the longitudinal fibres which pass into the pons from above do not pass out from it below into the medulla. What becomes of these fibres that are thus absorbed in the pons? It is known that the pyramidal bundles suffer a small loss by the fibres which

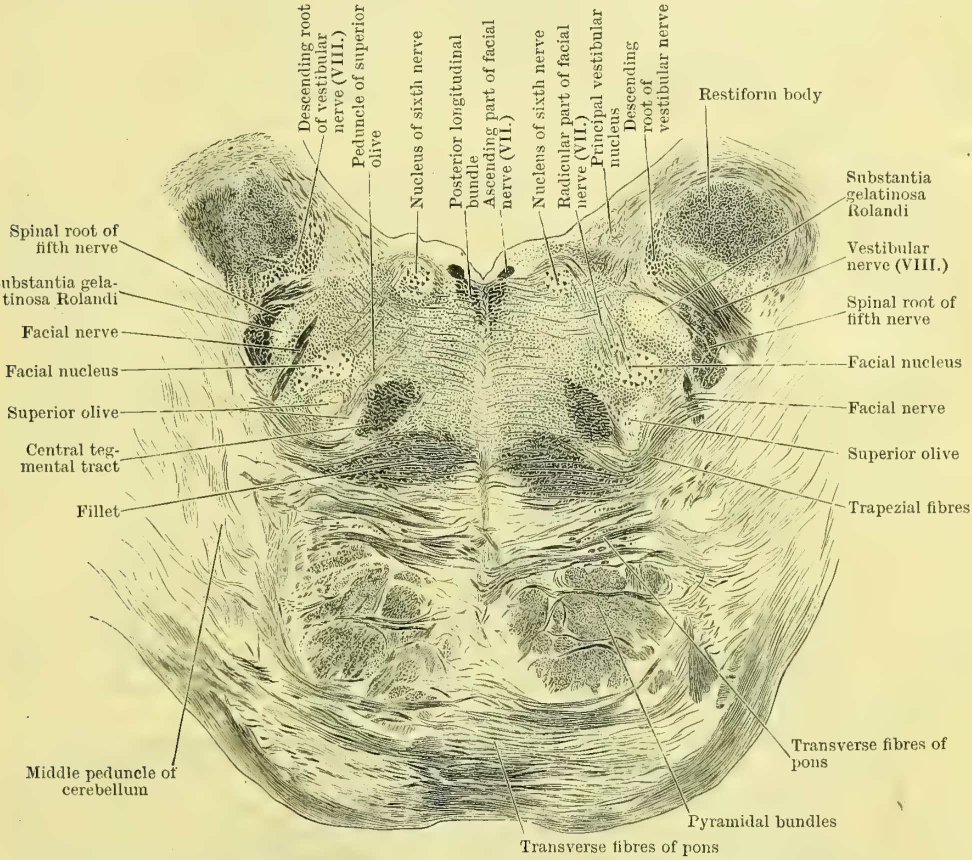


Fig. 344.—Section through the Lower Part of the Human Pons Varolii immediately above the Medulla.

they send to the nuclei of origin of the efferent nerves which arise within the pons (viz. the motor root of the fifth, the sixth, and seventh nerve nuclei); but this loss is, comparatively speaking, trifling. It is clear, therefore, that other longitudinal bundles enter the pons from above than those which form the pyramidal tracts. These bundles occupy a lateral and dorsal position in the ventral part of the pons, and may be termed the **cortico-pontine fibres**, seeing that they are supposed to come from the cerebral cortex and end in fine ramifications around the cells of the nucleus pontis.

The transverse fibres are of two kinds, viz.: (1) those which arise in the cortex of the cerebellum; and (2) those which take origin in the nucleus pontis. The former are the axons of certain of the cells of the cortex of the cerebellum (cells of Purkinje). They come chiefly from the lateral hemisphere, but also to some extent from the central lobe of the cerebellum, and enter the pons by the middle peduncle. They end in fine ramifications around the cells of the nucleus pontis, some on the same side as the peduncle through which they reach the pons, but the majority in the gray matter of the opposite side.

The transverse fibres which arise in the pons take origin as axons of the cells of the nucleus pontis. Crossing the mesial plane, they enter the middle peduncle of the opposite side, and thus reach the cerebellar cortex, where they end in ramifications round certain of the cortical cells. The middle peduncle thus contains both efferent and afferent cerebellar fibres, and no fibres pass continuously through the pons from one middle peduncle

into the other. In opposition to this view, Klimoff holds that the middle peduncle is composed solely of centripetal or afferent fibres, which pass from the nucleus pontis to the cerebellum. Some of these fibres are crossed and others direct.

Certain of the transverse fibres of the pons turn backwards and enter the dorsal or tegmental part of the pons, but the precise connexions of these are doubtful.

Corpus Trapezoides.—This name is applied to a group of transverse fibres which traverse the lower part of the pons. They are quite distinct from those which have been just described as entering the middle peduncle of the cerebellum, and they lie in the boundary between the dorsal and ventral parts of the pons, but encroaching considerably into the ground of the former. They arise from the cells of the terminal nucleus of the cochlear division of the auditory nerve, and constitute a tract which establishes certain central connexions for that nerve. They will be more fully described when we treat of the cerebral connexions of the auditory nerve.

Dorsal or Tegmental Part of the Pons (pars dorsalis pontis).—On the dorsal surface of the tegmental part of the pons there is spread a thick layer of gray matter, covered by ependyma, which forms the floor of the upper or pontine part of the fourth ventricle. Beneath this the mesial raphe of the medulla is continued up into the pons, so as to divide its tegmental part into two symmetrical halves.

In the *lower part of the pons*, immediately beyond the medulla, the restiform body is placed on the outer side of the tegmental part. In transverse sections through the pons it appears as a large, massive oval strand of fibres which gradually inclines backwards into the cerebellum, and thus leaves the pons. Between the restiform body and the median raphe the tegmental part of the pons is composed of formatio reticularis, continuous with the same material in the medulla. Thus arcuate or transverse fibres, curving in towards the raphe, and also longitudinal fibres, are seen breaking through a mass of gray matter which occupies the interstices of the intersecting fibres. To the naked eye the formatio reticularis presents a uniform gray appearance, but its constituent parts are revealed by low powers of the microscope in properly-stained and prepared specimens. Embedded in this formatio reticularis are various clumps of compact gray matter and certain definite strands of fibres. These we shall describe as we pass from the restiform body inwards towards the median raphe.

(1) **Spinal root of the trigeminal nerve and the substantia gelatinosa Rolandi.**—Close to the inner side of the restiform body, but separated from it by the vestibular root of the auditory nerve as it passes backwards through the pons, is seen a large crescentic group of coarse transversely-divided bundles of fibres. This is the spinal root of the fifth nerve, and applied to its inner concave side is a small mass of gray matter, which is the direct continuation upwards of the substantia gelatinosa Rolandi.

(2) The **nucleus of the facial or seventh nerve** comes next. It is sunk deeply in the tegmental part of the pons and lies close to the transverse fibres of the corpus trapezoides. It is a conspicuous, obliquely placed, ovoid clump of gray matter. From its outer and dorsal aspect the root-fibres of the facial nerve stream backwards and inwards towards the gray matter on the floor of the fourth ventricle. Passing forwards between this nucleus and the substantia Rolandi a solid nerve-bundle may be observed. This is the facial nerve, traversing the pons towards its place of emergence from the brain.

(3) Immediately internal to the facial nucleus, but placed more deeply in the tegmental part of the pons, is the **superior olivary nucleus** (nucleus olivaris superior). It lies in a bay formed for it by the transverse fibres of the corpus trapezoides. These fibres curve round its ventral aspect, and many of them may be observed penetrating into its substance. In man it is a very small mass of gray matter, and presents little resemblance to the inferior olivary nucleus, except in the size and shape of its constituent cells. In sections through the part of the pons where it attains its greatest size, it appears in the form of two, or it may be three, small isolated clumps of gray matter. It is intimately connected with the trapezial fibres, many of which end in it, whilst others take origin within it.

Upon the inner and dorsal aspect of the superior olive there is a dense group of longitudinal fibres. These constitute the **central tegmental tract**; but as precise information in regard to its connexions is still to a large extent wanting, it is not necessary to do more than indicate its position.

(4) The **posterior longitudinal bundle** and the **fillet** come next. As they proceed upwards through the tegmental part of the pons, these longitudinal tracts occupy the same relative position as in the medulla. They are placed close to the median raphe; but they have drawn further apart from each other, and their fibres are more distinctly concentrated into separate strands, with an interval of some little width between them. The **posterior longitudinal bundle** lies immediately under cover of the gray matter of the floor of the fourth ventricle. The **fillet** is placed close to the trapezial fibres, many of which traverse it as they pass towards the mesial plane.

(5) The **nucleus of the sixth nerve** also forms a conspicuous object in sections through the lower part of the pons. It is a round mass of gray matter, which lies close to the outer side of the posterior longitudinal bundle, and immediately under cover of the gray matter of the floor of the fourth ventricle. From its inner side numerous root-bundles of the sixth nerve pass out and proceed forwards between the fillet and the superior olivary nucleus. They occupy in the pons, therefore, a position similar to that occupied by the hypoglossal root-fibres in the medulla.

Up to the present only the lower part of the tegmental portion of the pons has been described, *i.e.* the portion immediately adjoining the medulla. As we proceed upwards and gain a point *above the level of the trapezial fibres*, many of

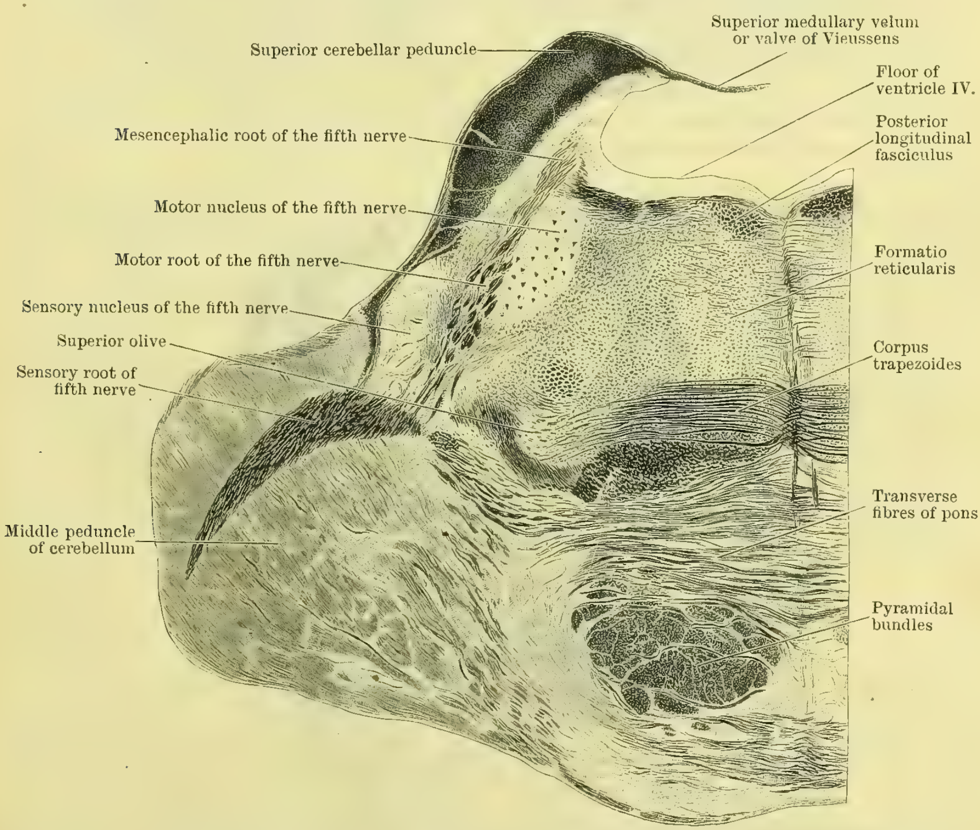


FIG. 345.—TRANSVERSE SECTION THROUGH THE PONS VAROLII AT THE LEVEL OF THE NUCLEI OF THE TRIGEMINAL NERVE (Orang).

the structures which have attracted attention lower down gradually disappear from the formatio reticularis. The posterior longitudinal bundle, the fillet, and the spinal root of the fifth nerve, however, are still carried upwards. Further, the

floor of the fourth ventricle becomes narrower, and other objects appear in the tegmental substance.

The **superior cerebellar peduncle** (brachium conjunctivum) is a very conspicuous object, in sections, through the middle and upper parts of the pons. In transverse section it presents a semilunar outline, and as it emerges from the cerebellum it lies immediately on the outer side of the fourth ventricle, towards which its concave aspect is turned (Fig. 345). Its dorsal border is joined with the corresponding peduncle of the opposite side by the thin lamina of white matter, termed the superior medullary velum, whilst its ventral border is sunk to a small extent in the dorsal part of the pons. As it is traced upwards it sinks deeper and deeper into the pons until it becomes completely submerged, with the exception of the posterior border to which the superior velum is attached. It now lies on the outer side of the tegmental or reticular substance of the pons, and this position it maintains until the mesencephalon is reached (Fig. 346).

About *half-way up the pons* the nuclei of the trigeminal or fifth cranial nerve mark a very important stage in its tegmental portion. These nuclei are two in number on each side, viz. a large oval terminal nucleus for certain of the sensory fibres of the nerve and a nucleus of origin equally conspicuous for certain of the motor fibres (Fig. 345). The **sensory nucleus** lies close to the outer surface of the pons, deeply sunk in its tegmental part, and in the interval between the submerged anterior border of the superior cerebellar peduncle and the ventral part of the pons. The **motor nucleus** is placed on the inner side of the sensory nucleus, but somewhat nearer the dorsal surface of the pons. At this level the spinal root of the fifth nerve disappears by joining the fibres of the sensory portion. The two roots of the fifth nerve traverse the ventral part of the pons on their way to and from the region of the nuclei.

Above the level of the nuclei of the trigeminal nerve a new tract of fibres comes into view. This is the **mesencephalic root** of the fifth nerve, as it descends to join the emerging fibres of the motor part of the fifth nerve. It is a small bundle of nerve fibres, semilunar in cross section, which lies close to the inner side

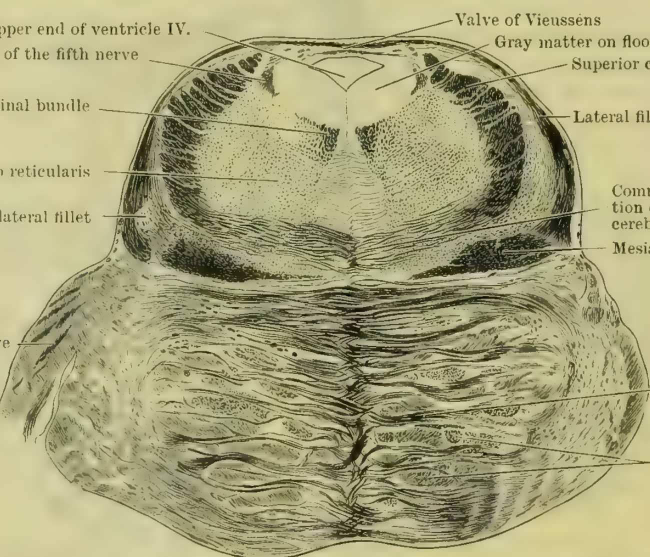


Fig. 346.—Section through the Upper Part of the Pons Varolii of the Orang, above the Level of the Trigeminal Nuclei.

of the superior cerebellar peduncle and on the outer and deep aspect of the gray matter on the floor of the fourth ventricle (Figs. 346 and 347).

On a slightly deeper plane than the mesencephalic root of the fifth nerve, between it and the posterior longitudinal bundle, and in close relation to the gray matter on the floor of the ventricle, is the collection of pigmented cells which constitute the **substantia ferruginea**.

The **posterior longitudinal bundle**, as it is traced upwards through the tegmental part of the pons, maintains the same position throughout, and as it ascends it becomes more clearly mapped out as a definite and distinct tract. It lies close to the mesial raphe and immediately subjacent to the gray matter of the floor of the fourth ventricle.

The **fillet** as it ascends through the tegmental part of the pons undergoes striking changes in shape. In the lower portion of the pons its fibres, which in the medulla are spread out along the side of the median raphe, are collected together in the form of a loose bundle, which occupies a wide field, somewhat triangular in shape, on either side of the median raphe and immediately behind

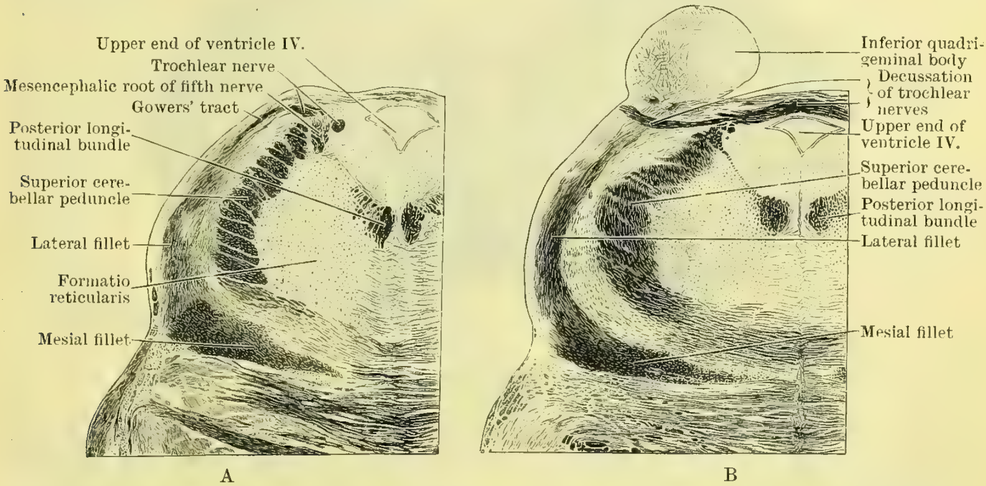


FIG. 347.—TWO SECTIONS THROUGH THE TEGMENTUM OF THE PONS AT ITS UPPER PART, CLOSE TO THE MESENCEPHALON.
A is at a slightly lower level than B.

the ventral portion of the pons. As it proceeds up, the fibres spread out laterally until a compact ribbon-like layer is formed in the interval between the tegmental and ventral portions of the pons. This constitutes what is termed the **mesial fillet** (Figs. 346 and 347).

Above the level of the trigeminal nuclei another flattened layer of fibres comes into view to the outer side of the mesial fillet. To this the name of **lateral fillet** is given. These fibres spread outwards and backwards, and finally take up a position on the outer surface of the superior cerebellar peduncle. In the angle between the mesial and lateral fillets a little knot of compact gray matter, termed the **lateral fillet nucleus**, comes into view (Fig. 346). This appears to be in more or less direct continuity with the superior olivary nucleus. Many of the fibres of the lateral fillet take origin in this nucleus. Bruce has called attention to the continuity between the superior olive and the lateral fillet nucleus in man, and the writer can confirm his statement in so far as the orang brain is concerned.

THE CEREBELLUM.

The **cerebellum** lies behind the pons Varolii and the medulla oblongata, and below the hinder portions of the cerebral hemispheres, from which it is separated by the intervening partition of dura mater, termed the tentorium cerebelli. It is distinguished by the numerous parallel and more or less curved sulci, which traverse its surface and give it a foliated or laminated appearance. It is composed of a cortex of gray matter (substantia corticalis) spread over its surface, with white matter in the interior, forming a central core (corpus medullare).

In the cerebellum we recognise a median portion termed the **vermis**, and two much larger lateral portions, called the **lateral hemispheres** (hemisphæria cerebelli). The demarcation between these main subdivisions of the organ is not very evident from every point of view. In front, and also behind, there is a marked deficiency

or notch. The **posterior notch** (incisura cerebelli posterior) is smaller and narrower than the anterior notch. It is bounded laterally by the lateral hemispheres, whilst its bottom is formed by the median lobe or vermis. It is occupied by a fold of dura mater, called the falx cerebelli. The **anterior notch** (incisura cerebelli anterior) is wide and shallow, and, when viewed from above, it is seen to be occupied by the

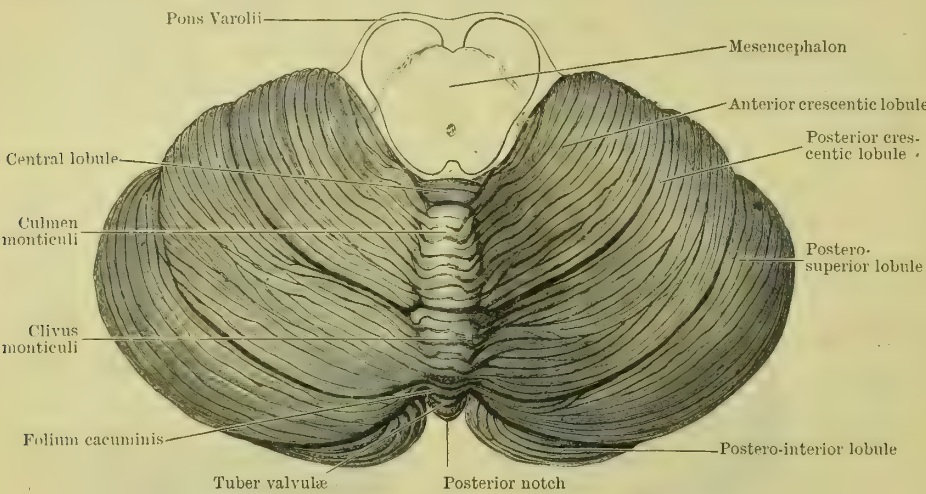


FIG. 348.—UPPER SURFACE OF THE CEREBELLUM.

inferior quadrigeminal bodies and by the superior peduncles of the cerebellum. As in the case of the hinder notch, its sides are formed by the lateral hemispheres and the bottom by the vermis.

On the superior surface of the cerebellum there is little distinction to be noted between the median lobe and the upper surface of each lateral hemisphere. On this aspect the median lobe receives the name of **superior vermis**, and it forms a high median elevation, from which the surface slopes gradually downwards on each side to the margin of the hemisphere. The superior vermis is highest in front, immediately behind the anterior notch, and from this it inclines downwards towards the posterior notch. This elevation of the superior worm is frequently called the monticulus cerebelli. The folia on the surface of the superior vermis are thicker and fewer in number than those on the upper surface of the lateral hemisphere. It is this which gives it the worm-like appearance from which it derives its name.

On the inferior surface of the cerebellum the distinction between the three constituent parts of the organ is much better marked (Fig. 349). On this aspect the lateral hemispheres are full, prominent, and convex, and are separated by a deep mesial hollow, which is continued forwards from the posterior notch. This hollow is termed the **vallecula cerebelli**, and in its fore-part is lodged the medulla oblongata. When the medulla is raised and the lateral hemispheres are pulled apart, so as to expose the bottom of the vallecula, it will be seen that this is formed by the **vermis inferior**, and, further, that the latter is separated on each side from the corresponding lateral hemisphere by a distinct furrow, termed the **sulcus valleculæ**.

Sulci Cerebelli.—Certain of the fissures which traverse the surface of the cerebellum are deeper and longer than the others, and they map out districts which are termed lobes. The most conspicuous of all these clefts is the great horizontal fissure.

The **great horizontal fissure** (sulcus horizontalis cerebelli) of the cerebellum begins in front and passes continuously round the circumference of the organ, cutting deeply into its outer and posterior margin. In front, its lips diverge to enclose the three cerebellar peduncles as they pass into the interior of the cerebellum. The great horizontal fissure divides the organ into an upper and a lower part, which may be studied separately.

Lobes on the Upper Surface of the Cerebellum.—When examined from before backwards, the superior vermis presents the following subdivisions: (1) the **lingula**; (2) the **central lobule** (lobulus centralis); (3) the **culmen monticuli**; (4) the **clivus monticuli**; (5) the **folium cacuminis** (folium vermis). With the exception of the lingula, each of these is continuous on either side, with a corresponding district on the upper surface of the hemisphere, thereby forming a cerebellar lobe. Thus the central lobule is prolonged outwards on either side in an expansion called the **ala**; the culmen constitutes the median connecting piece between the two **anterior crescentic lobules** of the hemispheres; the clivus stands in the same relation to the two **posterior crescentic lobules**; and the folium cacuminis is the connecting band between the **postero-superior lobules** of the hemispheres.

The **lingula** can only be seen when the part of the cerebellum which forms the bottom of the anterior notch is pushed backwards. It consists of four or five small folia continuous with the gray matter of the vermis superior, which are prolonged forwards on the upper surface of the superior medullary velum in the interval between the two superior cerebellar peduncles.

Lobus Centralis with its Alæ.—The lobulus centralis lies at the bottom of the anterior cerebellar notch, and is only seen to a very small extent on the upper surface of the organ. It is a little median mass which laterally is prolonged outwards for a short distance round the anterior notch in the form of two expansions, termed the alæ.

Lobus Culminis.—The culmen monticuli constitutes the highest part or summit of the monticulus of the vermis superior. It is prolonged outwards on either side into the lateral hemisphere as the **anterior crescentic lobule.** This is the most anterior subdivision on the upper surface of the hemisphere. The two anterior crescentic lobules, with the culmen monticuli, form the **lobus culminis cerebelli.**

Lobus Clivi.—The clivus monticuli lies behind the culmen, from which it is separated by a strongly marked fissure, and it forms the sloping part or descent of the monticulus of the vermis superior. On each side it is continuous with the **posterior crescentic lobule** of the lateral hemisphere, and the three parts are included under the one name of **lobus clivi.**

The two crescentic lobules on the upper surface of the hemisphere are sometimes classed together and described as the **lobulus quadrangularis.**

Lobus Cacuminis.—The folium cacuminis forms the most posterior part of the vermis superior, and it thus bounds the great horizontal fissure superiorly at the posterior notch. It is a single folium, the surface of which may be smooth or beset with rudimentary secondary folia. It is the median connecting link between the two **postero-superior lobules** of the hemispheres, the three parts forming the **lobus cacuminis.** As the folium cacuminis is traced outwards into the postero-superior lobule, it is found to expand greatly, and as a result of this the postero-superior lobule on each side forms an extensive foliated district bounding the great horizontal fissure above.

Lobes on the Under Surface of the Cerebellum.—The connexion between the several parts of the inferior vermis and the corresponding districts on the under surface of the two hemispheres is not nearly so distinct as in the case of the vermis superior and the lobules on the upper surface of the hemispheres. A groove, the **sulcus valleculæ,** intervenes between the vermis inferior and the hemisphere on each side.

From behind forwards the following subdivisions of the vermis inferior may be recognised: (1) the **tuber valvulæ** (tuber vermis); (2) the **pyramid** (pyramis); (3) the **uvula**; (4) the **nodule** (nodulus).

On the under surface of the hemisphere there are four main lobules mapped out by intervening fissures. From before backwards these are: (1) the **flocculus,** a little lobule lying upon the middle peduncle of the cerebellum; (2) the **biventral lobule** (lobulus biventer), which is placed immediately behind the flocculus and is partially divided into two parts by a curved fissure which traverses its surface; (3) the **tonsil** or **amygdala** (tonsilla), a rounded lobule which bounds the vallecula on the inner side of the biventral lobule; (4) the **postero-inferior lobule,** which is

situated behind the biventral lobule and bounds the great horizontal fissure below.

These lobules, with the corresponding portions of the vermis inferior, constitute the lobes on the under aspect of the cerebellum.

Lobus Noduli.—The lobus noduli comprises the nodule and the flocculus of

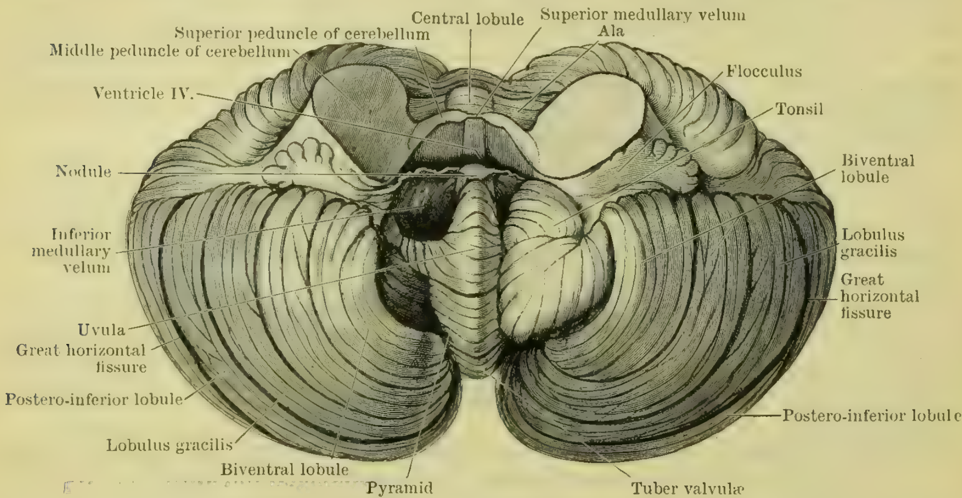


FIG. 349.—LOWER SURFACE OF THE CEREBELLUM.
The tonsil on the right side has been removed so as to display more fully the inferior medullary velum and the furrowed band.

each side, with a delicate connecting lamina of white matter, termed the **inferior medullary velum.**

Lobus Uvulæ.—The uvula is a triangular elevation of the vermis inferior which lies between the two tonsils. It is connected across the sulcus valleculæ with each tonsil by a low-lying ridge of gray matter scored by a few shallow furrows, and in consequence termed the **furrowed band.** The two tonsils and the uvula form the lobus uvulæ.

Lobus Pyramidis.—The pyramid is connected with the biventral lobule on each side by a faint ridge which crosses the sulcus valleculæ. The term lobus pyramidis is applied to the three lobules, which are thus associated with each other.

Lobus Tuberis.—The tuber valvulæ, which forms the most posterior part of the vermis inferior, is composed of several folia which run directly into the postero-inferior lobule on each side. The three parts of the lobus tuberis are thus linked together. The postero-inferior lobule is traversed by three curved fissures, which divide it more or less distinctly into four parts. Of these the two anterior form the **lobulus gracilis**, and the two posterior the **lobulus semilunaris inferior.**

Arrangement of the Gray and White Matter of the Cerebellum.—The white matter of the cerebellum forms a solid compact mass in the interior, and over this is spread a continuous and uniform layer of gray matter. In each lateral hemisphere the white central core is more bulky than in the median lobe or worm, in which the central white matter is reduced to a relatively thin bridge thrown across between the two lateral hemispheres. The white matter in the interior of the median lobe or worm is termed the **corpus trapezoides.** When sagittal sections are made through the cerebellum, the gray matter on the surface stands out clearly from the white matter in the interior. Further, from all parts of the surface of the central core stout stems of white matter are seen projecting into the lobes of the cerebellum. From the sides of these white stems secondary branches proceed at various angles, and from these again tertiary branches are given off. Over the various lamellæ of white matter thus formed the gray cortex is spread, and the fissures on the surface show a corresponding arrangement, dividing up the organ into lobes, lobules, and folia. When the cerebellum is divided at right angles to

the general direction of its fissures and folia, a highly arborescent appearance is thus presented by the cut surface. To this the term **arbor vitæ cerebelli** is applied.

Corpus Dentatum and other Gray Nuclei in the White Matter of the Cerebellum.—Embedded in the midst of the mass of white matter which forms the central core of each lateral hemisphere there is an isolated nucleus of gray matter, which presents a strong resemblance to the inferior olivary nucleus of the medulla. It is called the **corpus dentatum** (nucleus dentatus), and it consists of a corrugated or plicated lamina of gray matter, which is folded on itself so as to enclose, in a flask-like manner, a portion of the central white matter. This gray capsule is not completely closed. It presents an open mouth, termed the hilum, which is directed inwards and upwards, and out of this stream the great majority of the fibres of the superior cerebellar peduncle.

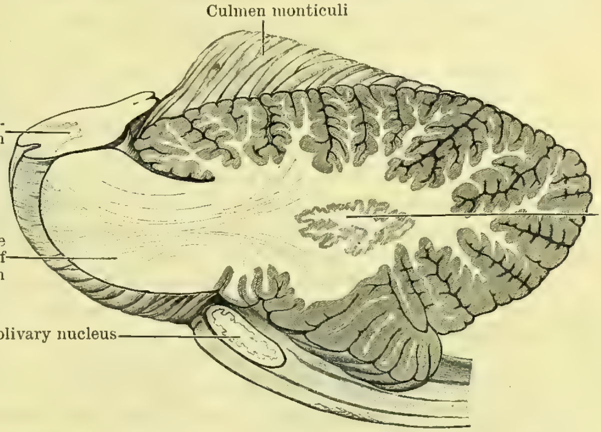


Fig. 350.—Sagittal Section through the Left Lateral Hemisphere of the Cerebellum,
Showing the "arbor vitæ" and the corpus dentatum.

Three small additional masses of gray matter are also present on either side of the mesial plane in the central white matter of the cerebellum. These are termed the nucleus emboliformis, the nucleus globosus, and the nucleus fastigii. The **nucleus emboliformis** or **embolus** is a small lamina of gray matter which lies immediately internal to the hilum of the corpus dentatum, being thus related to it somewhat in the same manner that the mesial accessory olivary nucleus is related to the main inferior olivary nucleus. The **nucleus globosus** lies internal to the embolus and on a somewhat deeper horizontal plane. The **nucleus fastigii** or **roof nucleus** is placed in the white substance of the worm (corpus trapezoides) close to the mesial plane and its fellow of the opposite side. It is, therefore, situated on the mesial aspect of the nucleus globosus.

Although isolated from the gray matter of the surface, these small nuclei and the corpus dentatum are connected at certain points with each other. The corpus dentatum and the embolus present a structure very similar to that of the inferior olivary nucleus. In the nucleus globosus and the nucleus fastigii the cells are somewhat larger in size.

Cerebellar Peduncles.—These are three in number on each side, viz. the middle, the inferior, and the superior. The fibres of which they are composed all enter or emerge from the white medullary centre of the cerebellum.

The **middle peduncle** is much the largest of the three, and has already been described on pp. 450 and 462. It is formed by the transverse fibres of the pons, and it enters the cerebellar hemisphere on the outer aspect of the other two peduncles. The lips of the anterior part of the great horizontal fissure are separated widely from each other to give it admission. Within the cerebellar hemisphere its fibres are distributed in two great bundles. Of these, one, composed of the upper transverse fibres of the pons, radiates out in the lower part of the hemisphere; whilst the other, consisting of the lower transverse fibres of the pons, spreads out in the upper part of the hemisphere.

The **inferior peduncle** is simply the restiform body of the medulla. After leaving the medulla it ascends for a short distance on the dorsal surface of the pons and then turns sharply backwards, to enter the cerebellum between the other two peduncles.

The **superior peduncle**, as it issues from the cerebellum, lies close to the inner side of the middle peduncle (Fig. 349). Its further course upwards on the dorsum of the pons to the inferior quadrigeminal body has been previously described (p. 451).

Connexions established by the Peduncular Fibres.—The fibres of the **middle**

peduncle are both afferent and efferent. The connexions which they establish in the pons are described on p. 463. The efferent fibres arise from cells in the gray cortex of the lateral hemisphere (also probably to some small extent in the cortex of the vermis), and end in connexion with the cells of the nucleus pontis, and likewise in the tegmental part of the pons. The afferent fibres, arising in the pons, end in the gray cortex of the lateral hemisphere of the cerebellum, and perhaps also in the cortex of the worm.

The **inferior peduncle** is also composed of afferent and efferent fibres (see p. 459); only the more important connexions which these establish in the cerebellum can be touched on here. The principal afferent strand is the *direct cerebellar tract.* The fibres of this strand end in the cortex of the superior worm on both sides of the mesial plane, but chiefly on the opposite side. The principal efferent tract consists of the *cerebello-olivary fibres,* and the precise origin of these is doubtful. It appears probable that they come from cells in the cortex of both the worm and hemisphere, and also from cells in the nucleus dentatus. The numerous *arcuate fibres* which enter the inferior peduncle establish connexions with cells in the cortex of the lateral hemisphere and of the worm.

The **superior peduncle** is an efferent tract. The majority of its fibres come from the cells of the nucleus dentatus, whilst a small proportion appear to come from the cerebellar cortex. According to Risien Russell, the fibres which form the dorsal edge of the band come from the opposite side of the cerebellum and cross the mesial plane to join the peduncle.

Our knowledge of the connexions of the peduncles of the cerebellum has been greatly extended by Ferrier and Aldren Turner; and the account which is given above, and also at p. 463, is largely derived from their memoir on this subject.

As already mentioned, the views of Klimoff upon the cerebellar connexions do not coincide with those expressed above. He believes that the efferent tracts to the parts above (viz. the mesencephalon and cerebrum) are the superior cerebellar tracts; whilst the efferent tracts to the parts below are the direct sensory cerebellar tracts of Edinger (*vide* p. 482), which spring from the vermis and pass down to Deiters's nuclei. From these internodes tracts proceed downwards in the antero-lateral columns of the cord as far as the lumbar region. These latter are termed Lowenthal's anterior marginal bundles. Further, according to Klimoff, the middle and inferior peduncles are entirely afferent—the former binding the cerebellum to the cerebral cortex through the nucleus pontis as an internode, and the latter binding it to the medulla and cord.[1]

Commissural and Association Fibres.—In addition to those fibres of the white medullary centre which belong to the system of peduncles, there are others which have exclusively cerebellar connexions. Thus the various folia are bound together by numerous **association fibres,** which pass from one folium into another around the bottom of the intervening fissure. Tracts of transversely-directed **commissural fibres** cross the mesial plane in the white centre of the vermis, connecting corresponding parts of opposite sides. These, in some measure, are analogous to the corpus callosum of the cerebrum. The **roof nuclei** are also closely bound by connecting fibres with the cortex.

Medullary Vela.—The medullary vela are closely associated with the cerebellar peduncles. They consist of two thin laminæ of white matter, which are projected out from the white central core of the cerebellum.

The **superior medullary velum** is described on p. 451. Laterally, it is continuous with the dorsal edges of the superior cerebellar peduncles; whilst, inferiorly, it is prolonged downwards and backwards under the lingula and the central lobule of the superior worm, to become continuous with the central white matter or corpus trapezoides of the worm.

The **inferior medullary velum** is more complicated in its connexions. It presents much the same relations to the nodule of the inferior vermiform process that the superior velum presents to the lingula of the superior vermiform process. It is a wide thin lamina of white matter—so thin that it is translucent—which is prolonged out from the white centre of the cerebellum above the nodule. From the nodule it stretches outwards to the flocculus on each side, thereby bringing these three small portions of the cerebellum into association with each other (Fig. 349). Where it issues from the white matter of the cerebellum it is in contact with the superior medullary velum, but, as the two laminæ are traced forwards, they immediately diverge from each other. The superior velum is carried upwards between the two superior cerebellar peduncles, whilst the inferior medullary velum is curved forwards and then downwards round the nodule, and ends at a variable point in a free, slightly thickened, crescentic edge. The cavity of the fourth

ventricle is carried backwards into the cerebellum between the two vela, which thus form a peaked and tent-like roof for it.

Relation of the Tract of Gowers to the Superior Medullary Velum.—The ascending tract of Gowers has been noticed in connexion with the lateral column of the cord (p. 433). The fibres which compose it are carried upwards through the formatio

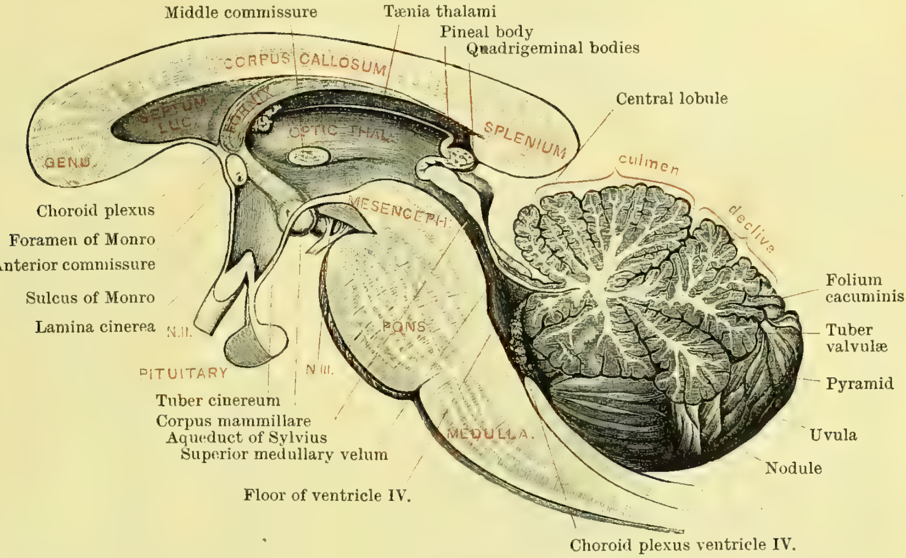


FIG. 351.—MESIAL SECTION THROUGH THE CORPUS CALLOSUM, THE MESENCEPHALON, THE PONS, MEDULLA, AND CEREBELLUM,
Showing the third and fourth ventricles joined by the aqueduct of Sylvius.

reticularis grisea of the medulla and the corresponding part of the tegmental portion of the pons. In this part of its course the fibres are scattered and do not form a compact strand. Reaching the upper end of the pons the tract turns backwards, enters the superior medullary velum, and proceeds downwards in it into the cerebellum.

Roof of the Fourth Ventricle.—In its upper part the roof of the fourth ventricle is formed by the superior medullary velum as it stretches across between the two superior cerebellar peduncles, and also, to some extent, by the approximation of these peduncles themselves as they approach the mesencephalon.

In its lower part the roof of the ventricle is exceedingly thin and is not all formed of nervous matter. The inferior medullary velum enters into its formation, and, where this fails, the epithelial lining of the cavity, supported by pia mater, is carried downwards towards the lower boundaries of the floor of the ventricle. At the lowest part of the calamus scriptorius, and also along each lateral boundary of the floor, a thin lamina of white matter is carried for a short distance over the epithelial roof. The small lamina at the calamus scriptorius overhangs the opening of the central canal, and is termed the **obex**. The lamina in connexion with the lateral boundary of the ventricular floor is more extensive, and is called the **ligula** (Figs. 333 and 335). It begins on the clava and passes upwards over the cuneate tubercle to the restiform body. On the outer surface of the restiform body it turns outwards so as to bound the lateral recess of the ventricle below, and in some cases it may be seen to become continuous around the extremity of the lateral recess with the inferior medullary velum.

A short distance above the calamus scriptorius there is, in the mesial plane, an opening in the epithelial and pial roof of the ventricle, by which the cavity of the ventricle communicates with the subarachnoid space. This opening is termed the **foramen of Majendie**. There is also an aperture of a similar nature in the epithelial and pial roof at the extremity of each lateral recess.

Two **choroid plexuses**, or highly vascular infoldings of the pia mater, invaginate the lower part of the roof of the fourth ventricle. These are placed one on either

side of the mesial plane, and, although they appear to lie within the cavity, they are in reality excluded from it by the epithelial lining of the ventricle, which covers over and is adapted to every sinuosity on their surface.

Two lateral offshoots from these longitudinal choroid plexuses proceed outwards, and protrude in a similar manner into the lateral recesses.

Minute Structure of a Cerebellar Folium.

A cerebellar folium is composed of a central core of white matter, covered by a layer of gray matter. The gray cortex is arranged in two very evident layers, viz. a superficial **molecular layer** and a subjacent rust-coloured **granular layer**. Between these strata a single layer of large cells, termed the **cells of Purkinje**, are disposed in the form of a very nearly continuous sheet. The cells of Purkinje constitute the most characteristic, and probably the most essential, constituents of the cerebellar cortex.

The **cells of Purkinje** are most numerous on the summit of the folium, and at the bottom of the sulci which intervene between the folia they become fewer in number, and, therefore, looser in their arrangement. Each consists of a large flask-shaped or pyriform cell body, the narrow end of which projects into the molecular layer, whilst the thicker, deeper end rests on the granular layer. From the latter arises a **single axon**, which passes into the granular layer and presents the peculiarity of almost immediately assuming its medullary sheath. From this axon a few collateral branches soon arise, which, taking a recurrent course, enter the molecular layer, to end in connexion with certain of the adjoining cells of Purkinje. They would seem to have the function of binding together adjacent cells, and thus enabling them to carry on their operations in harmony with each other.

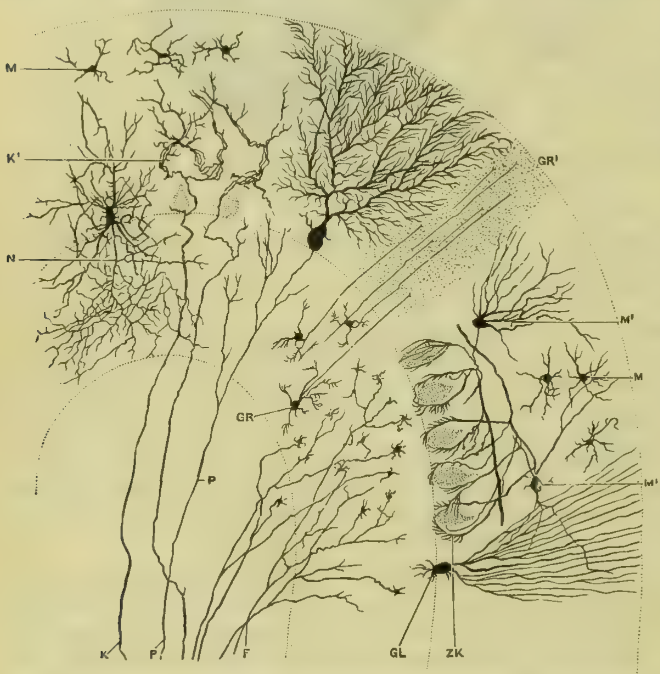


Fig. 352.—Transverse Section through a Cerebellar Folium (after Kölliker),

Treated by the Golgi method.

P. Axon of cell of Purkinje.
F. Moss fibres.
K and K[1]. Fibres from white core of folium ending in molecular layer in connexion with the dendrites of the cells of Purkinje.
M. Small cell of the molecular layer.
GR. Granule cell.
GR.[1] Axons of granule cells in molecular layer cut transversely.
M[1]. Basket-cells.
ZK. Basket-work around the cells of Purkinje.
GL. Neuroglial cell.
N. Axon of an association cell.

The **dendritic processes** spring from the narrow end of the cell either in the form of one or perhaps two stout stalks. These ascend into the molecular layer, branching and rebranching until an arborescent arrangement of extraordinary richness and extent results. The dendritic branches extend throughout the entire thickness of the molecular layer, and the branching takes place in one plane only, viz. in a plane which is transverse to the long axis of the folium. Consequently, it is only when transverse sections are made through a folium that the full dendritic effect is obtained; in sections made parallel to the long axis of the folium the cells are seen in profile and are observed to occupy quite a narrow area. The branching of the dendrites of a cell of Purkinje may, therefore, be compared to that which takes place in the case of a fruit-tree which is trained against a wall.

In the **molecular layer** the cells are not particularly numerous, and of these the

most characteristic are the **basket-cells**, which lie in the deeper part of the layer. In addition to numerous dendrites the basket-cell gives off an axon, which runs transversely, as regards the long axis of the folium, between the planes of adjacent dendritic arborisations of the cells of Purkinje. At first very fine these axons gradually become coarse and thick, and at intervals they give off collaterals, which run towards the bodies of the cells of Purkinje. Reaching these, they break up into an enormous number of fine terminal branches, which enclose the cells of Purkinje, as well as the short non-medullated portions of their axons, in a close basket-work of fine filaments.

The **granular layer** is, for the most part, composed of large numbers of small granule-like bodies closely packed together. Each of these possesses a somewhat large nucleus, with a very small amount of surrounding protoplasm. From the cell body three or four, or perhaps five, dendrites and one axon proceed. The **dendrites** are short and radiate out from different aspects of the cell body. They end in tufts of claw-like twigs, which either embrace or are otherwise in contact with neighbouring granule-cells. The whole multitude of granule-cells, therefore, are brought into intimate connexion with each other. The **axon** passes into the molecular layer, in which it ends at a varying distance from the surface by dividing into two branches. These diverge so sharply from each other that they almost form a right angle with the parent stem, and they run parallel to the long axis of the folium, threading their way between the branches of the various dendritic planes of the cells of Purkinje and entering into contact association with them. When the great number of granule-cells is borne in mind, and the fact that each sends an axon into the molecular layer, the important part which these fibres, with their longitudinal branches, take in building up the molecular layer will be understood. They are found pervading its entire thickness—from the surface down to the bodies of the cells of Purkinje.

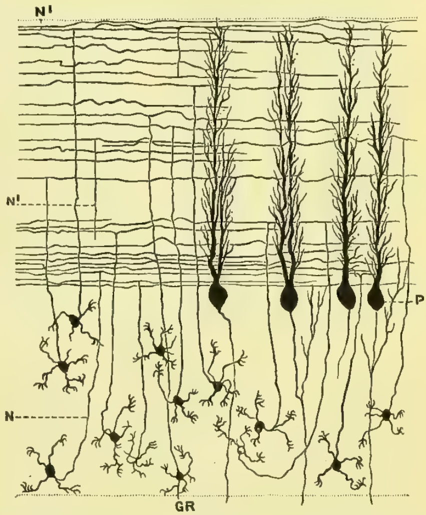


Fig. 353.—Section through the Molecular and Granular Layers in the Long Axis of a Cerebellar Folium (after Kölliker), Treated by the Golgi method.

P. Cell of Purkinje.
GR. Granule cells.
N. Axon of a granule cell.
N¹. Axons of granule cells in molecular layer.

Near the cells of Purkinje a few scattered cells are seen in the granular layer of a different kind. These are much larger than the ordinary granule-cells, and are probably of the nature of association cells. They are stellate in form, and have numerous long branching dendrites and an axon which divides up in the granular layer to a singular extent.

The **white centre** of the folium gradually becomes thinner as it approaches the summit. This is due to the fibres which compose it gradually entering the gray matter on the surface. These fibres are of three kinds, viz.: (1) axons of the cells of Purkinje; (2) fibres which apparently end in the granular layer; and (3) fibres which end in the molecular layer.

The **axons of the cells of Purkinje** are medullated fibres which, entering the white centre of the folium, form a not inconsiderable part of it.

The fibres which end in the granular layer are called **moss-fibres**. This name is applied to them because, in the granular layer, they present at certain points moss-like thickenings, from which short rough twigs proceed.

The fibres which proceed into the molecular layer give off few or perhaps no branches as they traverse the granular layer. In the deeper part of the molecular layer they break up into varicose branches, which twine around the primary and secondary stems of the Purkinje dendrites.

Entering into the constitution of the **molecular layer** are the following elements: (1) dendrites of the cells of Purkinje; (2) basket-cells and somewhat smaller cells nearer the surface; (3) axons of the granule-cells, with their longitudinally arranged branches; (4) the terminations of certain fibres from the white core of the folium, which end in contact with the Purkinje dendrites.

In the **granular layer** are found: (1) granule-cells; (2) larger stellate association cells; (3) axons of the cells of Purkinje; (4) moss-fibres; (5) fibres traversing this layer, to end in the molecular layer.

THE DEEP CONNEXIONS OF THE CRANIAL NERVES ATTACHED TO THE MEDULLA AND PONS.

There are twelve pairs of cranial nerves, of which the lower eight are attached to the medulla and pons Varolii. From above downwards these are named the fifth or trigeminal, the sixth or abducent, the seventh or facial, the eighth or auditory, the ninth or glosso-pharyngeal, the tenth or vagus, the eleventh or spinal accessory, and the twelfth or hypoglossal. The hypoglossal, the spinal accessory, the greater part of the facial, the abducent, and the motor root of the trigeminal are efferent nerves; the auditory, the pars intermedia of the facial, and the sensory root of the trigeminal are purely afferent nerves; whilst the vagus and glosso-pharyngeal are composed of both efferent and afferent fibres. In all cases, afferent fibres arise from ganglionic cells placed outside the brain and penetrate the brain-stem, to end in connexion with the cells of certain **nuclei of termination**. Efferent fibres, on the other hand, take origin within the brain as the axons of cells which are grouped together in certain places in the form of **nuclei of origin**.

Nuclei of Origin, or Motor Nuclei.—In the spinal cord there is a continuous nucleus of origin or column of cells running within the whole length of the anterior horn of gray matter, from which the series of efferent anterior nerve-roots take origin. In the medulla and pons the nuclei of origin, or, in other words, the motor nuclei, become discontinuous, and are represented by certain more or less isolated clumps of compact gray matter, in which are placed the clusters of cells from which the fibres of the efferent nerves arise. At the decussation of the pyramids, the anterior horn of gray matter of the cord is broken up by the intercrossing bundles into a detached head and a basal part which remains in relation with the ventro-lateral aspect of the central canal. Certain of the efferent or motor nuclei of the medulla and pons lie in the line of the basal portion of the ventral horn of gray matter of the spinal cord, and thus close to the mesial plane. These are termed **mesial nuclei of origin**, and are met with at different levels in the brain-stem. This group comprises the hypoglossal nucleus, the abducent nucleus (and, in the mesencephalon, the trochlear nucleus and the oculo-motor nucleus). Other motor nuclei of origin are present in the form of isolated clumps of gray matter, which lie at different levels in the medulla and pons in the line of the detached head of the anterior horn of gray matter. They are the medullary nucleus of the spinal accessory, the nucleus ambiguus of the vagus and glosso-pharyngeal, the facial nucleus, and the nucleus of the motor root of the trigeminal nerve. From their position in the tegmental substance of the medulla and pons, they constitute a group to which the name of **lateral motor nuclei** is applied. The different nuclei of origin of the efferent fibres which belong to the various cranial nerves, both mesial and lateral, are connected with the motor area of the cerebral cortex by fibres from the pyramidal tract, which enter the nuclei and end in connexion with their cells.

Nuclei of Termination.—In the brain the nuclei of termination are likewise discontinuous, and are represented by more or less isolated clusters of cells. Unlike the motor nuclei, however, these nuclei show no regular or definite position within the medulla and pons. Some are found in the gray matter which surrounds the central canal, and, in its continuation upwards, as the gray matter in the floor of the fourth ventricle; others are placed in the tegmental substance; whilst two actually lie on the surface of the brain-stem, viz. the lateral and ventral nuclei of the cochlear or outer division of the auditory nerve. The axons of the cells of the nuclei of termination enter the reticular formation of the tegmental substance as arcuate fibres, and, crossing the mesial plane, are carried upwards in the tegmental substance of the opposite side to establish direct or indirect connexions with the cerebral cortex.

Hypoglossal Nerve (nervus hypoglossus).—The nucleus of origin of the hypoglossal nerve, the motor nerve of the tongue, lies in the substance of the medulla oblongata. It is composed of several groups of large multipolar cells, which closely resemble the cells in the ventral horn of gray matter in the spinal cord, and is

pervaded by an intricate network of fine fibrils. In form it is elongated and rod-like, and in length it is somewhere about 18 mm. It extends from a point immediately above the decussation of the pyramids up to the level of the striæ acusticæ. The lower portion of the nucleus is thus placed in the closed part of the medulla (Fig. 340, p. 457), whilst its upper part is situated in the open part of the medulla (Fig. 343, p. 460). The former lies in that part of the central gray matter which is continuous with the basal part of the ventral horn of gray matter of the cord. It is thus placed on the ventral and lateral aspect of the central canal, close to the mesial plane and the corresponding nucleus of the opposite side. The upper part of the nucleus occupies a position in the gray matter on the floor of the fourth ventricle, subjacent to the surface area, which has been described under the name of the trigonum hypoglossi. Within the nucleus the axons of the cells arrange themselves in converging bundles of fine fibrils, which come together and leave the ventral aspect of the nucleus as the fasciculi of the nerve. The nerve bundles thus formed traverse the entire antero-posterior thickness of the medulla between the formatio reticularis grisea and the formatio reticularis alba, and emerge on the surface in linear order at the bottom of the furrow between the olivary eminence and the pyramid. In the substance of the medulla, the root-bundles of the hypoglossal pass between the main inferior olivary nucleus and the mesial accessory olivary nucleus, and many of them on their way to the surface pierce the ventral lamina of the main olivary nucleus.

No decussation between the nerves of opposite sides takes place in the medulla, but commissural fibres pass between the two nuclei (Kölliker). Further, numerous fibres from the opposite pyramidal tract enter the nucleus and end in connexion with its cells. The nucleus is thus brought into connexion with the motor area of the opposite side of the cerebral cortex.

Spinal Accessory Nerve (nervus accessorius).—The spinal accessory is likewise a motor nerve, and it is generally described as consisting of a spinal and a medullary or accessory part.

The **spinal part** of the nerve emerges by a series of roots, which issue from the surface of the lateral column of the upper part of the cord as low down as the fifth cervical nerve. These take origin in a column of cells situated in the anterior horn of gray matter of the cord close to its lateral margin, and immediately behind the

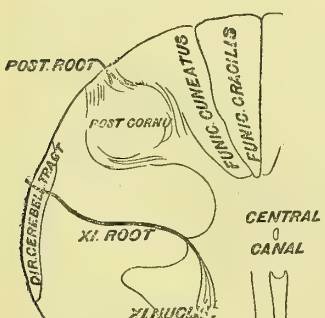


FIG. 354.—DIAGRAM OF THE SPINAL ORIGIN OF THE SPINAL ACCESSORY NERVE (after Bruce).

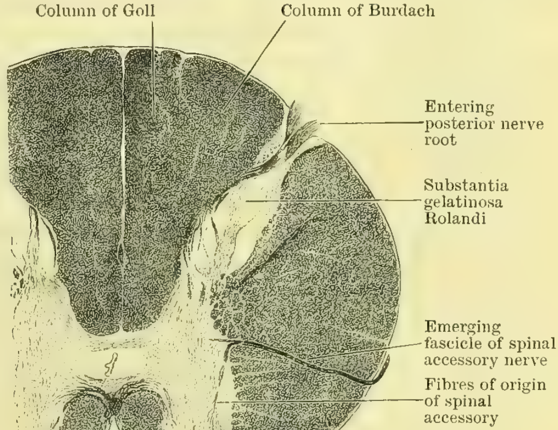


FIG. 355.—SECTION THROUGH THE UPPER PART OF THE CERVICAL REGION OF THE CORD (Orang), Showing the origin of the spinal part of the spinal accessory nerve.

nerve-cells which give rise to the fibres of the anterior roots of the upper five cervical nerves. The cells of the accessory nucleus are large, multipolar, and in every respect similar to the motor cells of the spinal nerves. The axons from these

cells leave the dorsal aspect of the nucleus in converging groups to form the root-bundles of the nerve. These, in the first place, proceed straight backwards in the anterior horn of gray matter. Reaching the bay between the two horns of gray matter, they turn sharply outwards into the white matter and traverse the lateral column to gain their points of exit from the cord. At the decussation of the pyramids, root-bundles, which join the spinal accessory nerve, are seen to proceed from the detached head of the anterior horn of gray matter.

The **medullary part** of the spinal accessory nerve has its nucleus of origin in the medulla; and its root-bundles, as they proceed outwards from this, can be distinguished by the fact that they pursue a course on the ventral side of the spinal root of the trigeminal nerve, whereas the vagus roots, with which they are apt to be confused, pass through or lie on the dorsal aspect of the trigeminal root (Kölliker). The nucleus of origin of the medullary part of the accessory nerve is formed by the same column of cells which constitutes the **nucleus ambiguus**, and which, at a higher level, gives motor fibres to the vagus and glosso-pharyngeal nerves.

It is usual to describe the medullary part of the spinal accessory nerve as arising in the nucleus of termination of the afferent part of the vagus. In the present state of our knowledge this is inconsistent with the fact that the medullary part of the spinal accessory is a motor nerve which supplies the muscles of the larynx, etc. Collaterals and fibres of the opposite pyramidal tract end in connexion with the cells of origin of the accessory nerve, and thus bring its nucleus into connexion with the motor area of the cerebral cortex. Fibres also from the posterior roots of the spinal nerves (afferent or sensory fibres) end in the nucleus.

Vagus and Glosso-pharyngeal Nerves (nervus vagus, nervus glosso-pharyngeus).—These nerves present similar connexions with the brain, and they may therefore be studied together. The greater part of both nerves is composed of afferent fibres, which arise outside the brain-stem from ganglionic cells placed in relation to the nerve-trunks. Both nerves likewise possess motor or efferent fibres, which spring from a special nucleus of origin situated within the medulla and termed the **nucleus ambiguus**. The afferent ganglionic fibres of the vagus and glosso-pharyngeal enter the brain by a series of roots which penetrate the medulla along the outer or ventral side of the restiform body. Within the medulla they separate into two sets, viz. a series of bundles (chiefly composed of vagus fibres), which end in the **nucleus of termination** of the vagus and glosso-pharyngeal nerves, and another series of bundles (chiefly composed of glosso-pharyngeal fibres), which join a conspicuous longitudinal tract of fibres called the **fasciculus solitarius**.

The **nucleus of termination** (Figs. 341, p. 458, and 343, p. 460) of the vagus and glosso-pharyngeal nerves very nearly equals in length the nucleus of the hypoglossal nerve, with which it is closely related. Above, it reaches as high as the striæ acusticæ, whilst below its lower end falls slightly short of that of the hypoglossal nucleus. In specimens stained by the Weigert-Pal method the two nuclei offer a marked contrast. The hypoglossal nucleus presents a dark hue, owing to the enormous numbers of fine fibres which twine in and out amidst its cells; the vago-glosso-pharyngeal nucleus is pale from the scarcity of such fibres within it. In the closed part of the medulla the vago-glosso-pharyngeal nucleus lies in the central gray matter immediately behind the hypoglossal nucleus; in the open part of the medulla it lies in the gray matter of the floor of the fourth ventricle, immediately to the outer side of the hypoglossal nucleus and subjacent to the surface area termed the trigonum vagi. Its cells are spindle-shaped in form and very similar to those found in the posterior horn of gray matter in the cord. In connexion with these cells, the greater number of the afferent fibres of the vagus nerve, and a small proportion of the afferent fibres of the glosso-pharyngeal nerve end in fine terminal arborisations. A small part of the upper portion of the nucleus may be said to belong to the glosso-pharyngeal nerve and the remainder of the nucleus to the vagus nerve.

Several authorities consider the nucleus which we have described as the *terminal nucleus* of the vagus and glosso-pharyngeal to be in reality a *nucleus of origin*, and to give off motor fibres, which enter these nerves. Quite recently Dr. A. Bruce has lent to this theory the weight of his name and experience.

The **fasciculus solitarius** (Figs. 340, p 457; 341, p. 458; and 343, p. 460) is a

round bundle of longitudinal fibres which forms a very conspicuous object in transverse sections through the medulla. It begins at the upper limit of the medulla, and can be traced downwards through its whole length. Its precise point of termination is not known, but it is believed that it is carried for some distance downwards into the upper part of the cord, viz. to the level of the fourth cervical nerve, according to Kölliker. The relations of the fasciculus solitarius are not the same in all parts of its course. It lies immediately to the outer side of the vago-glosso-pharyngeal nucleus; but whereas in the upper part of the medulla it is situated somewhat on the ventral side of that nucleus, in the lower closed part of the medulla it is placed on its dorsal aspect. Throughout its entire length it is intimately associated with a column of gelatinous gray substance which constitutes the nucleus of termination, in which its fibres end. When traced from above downwards, the solitary tract is observed to become gradually smaller from the loss of fibres which it thus sustains. The great bulk of the solitary tract is formed of fibres derived from the glosso-pharyngeal nerve; only a few of the afferent fibres of the vagus enter it. As the fibres of the two nerves join the tract they immediately turn downwards, and at different levels come to an end in the associated gelatinous gray nucleus.

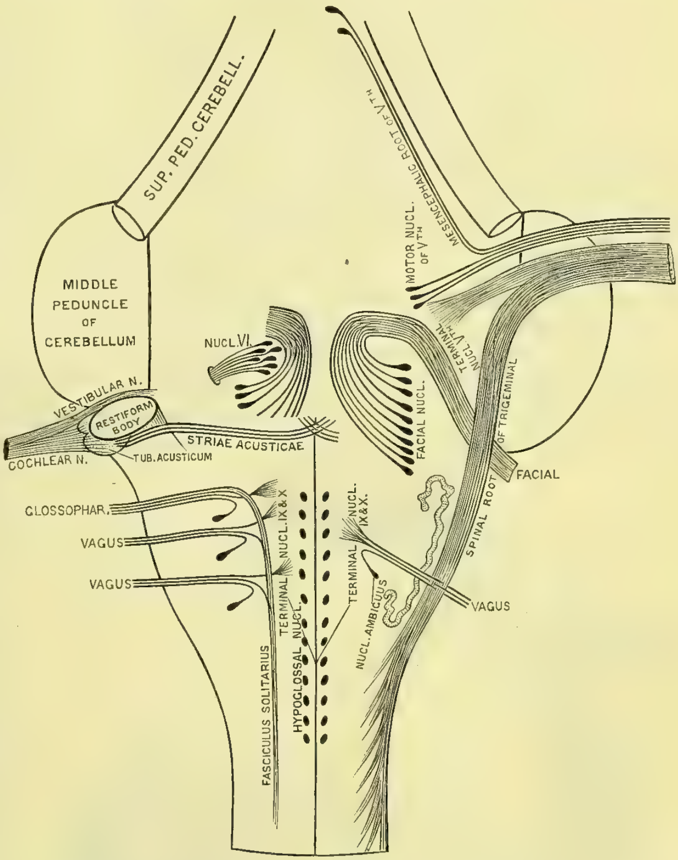


Fig. 356.—Diagram, showing the brain connexions of the vagus, glosso-pharyngeal, auditory, facial, abducent, and trigeminal nerves (founded on a somewhat similar diagram by Obersteiner).

As the root-bundles of the vagus and the glosso-pharyngeal nerves traverse the substance of the medulla in a backward and inward direction to reach the fasciculus solitarius and the nucleus of termination, they pass through the spinal root of the trigeminal nerve and the substantia gelatinosa Rolandi associated with it. The term **ascending root** is sometimes applied to the fasciculus solitarius; but as this conveys an altogether false conception of its character, it should be discarded. The axons of the nucleus of termination and of the nucleus of the fasciculus solitarius form central connexions with other parts of the brain, but these have not as yet been completely elucidated.

The **nucleus ambiguus** (Figs. 341, p. 458, and 343, p. 460) is the nucleus of origin of the motor or efferent fibres which join the vagus and glosso-pharyngeal nerves. The cells which compose it are large, multipolar, and similar in every respect to the large cells in the ventral horn of gray matter of the spinal cord. These cells are arranged in a slender column which is best developed in the upper open part of the medulla. Here the nucleus can easily be detected in transverse sections as a small area of compact gray matter which lies in the formatio reticularis grisea, midway between the dorsal accessory olive and the substantia gelatinosa Rolandi. It therefore lies more deeply in the substance of the

medulla than the vago-glosso-pharyngeal nucleus of termination. Kölliker states that it can be traced downwards as low as the level of the decussation of the fillet, and upwards as high as the place of entrance of the cochlear root of the auditory nerve. From its dorsal aspect the axons of the cells proceed, and in the first instance they pass backwards towards the floor of the fourth ventricle; then, bending suddenly outwards and forwards, they join the afferent roots of the vagus and glosso-pharyngeal nerves, and emerge from the brain in company with these.

Auditory Nerve (nervus acusticus).—This is a large nerve which joins the brain at the lower border of the pons Varolii and on the ventral aspect of the restiform body. It is an afferent nerve, and its fibres spring from bipolar ganglionic cells either within or in the immediate neighbourhood of the labyrinth or internal ear (see section dealing with the organs of sense). Reaching the brain the auditory nerve divides into two parts, viz. the nervus cochlearis and the nervus vestibularis, which present totally different connexions and apparently exercise absolutely distinct functions. In their further course these two divisions deviate from each other so as to embrace the restiform body—the vestibular part entering the pons on the inner or mesial aspect of the restiform body, whilst the cochlear part sweeps round its outer surface. Special nuclei of termination require to be studied in connexion with each part of the nerve.

The **cochlear nerve** is composed of finer fibres than the vestibular nerve, and these acquire their medullary sheaths at a later period. It is the true nerve of hearing, and its fibres end in a ganglion which lies in intimate relation to the restiform body, and which may be described as consisting of two parts. Of these one, called the **tuberculum acusticum** or the **lateral cochlear nucleus,** is a pyriform mass which is placed on the outer aspect of the restiform body—between it and the flocculus of the cerebellum. The second part, termed the **ventral cochlear nucleus,** does not extend so low down as the tuberculum acusticum. It is a wedge-shaped nuclear mass which is placed on the ventral aspect of the restiform body in the interval between the cochlear and vestibular divisions of the auditory nerve, after they have separated from each other. The fibres of the cochlear nerve enter these two ganglia and end around the cells in terminal arborisations, which are finer, closer, and more intricate than those met with in any other nerve nucleus in the brain.

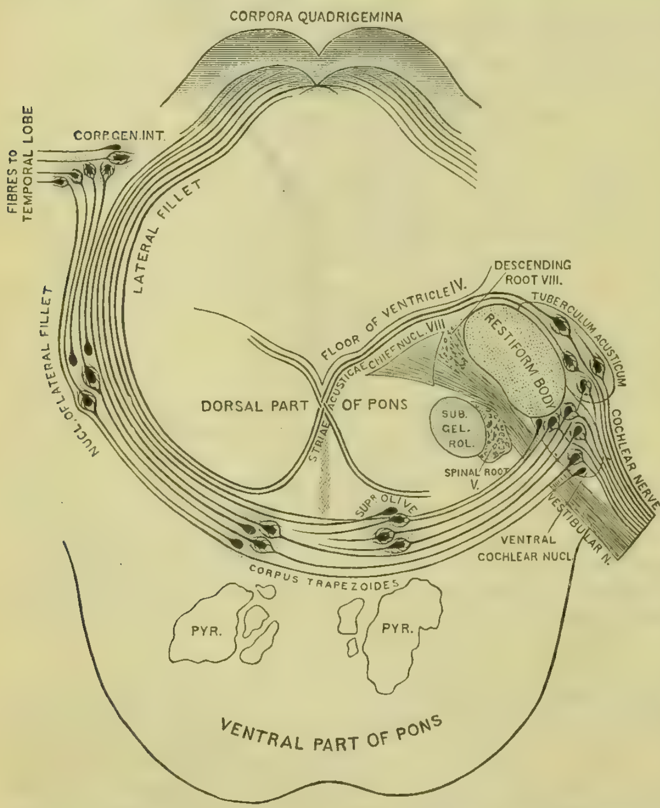


FIG. 357.—CENTRAL CONNEXIONS OF THE COCHLEAR AND VESTIBULAR DIVISIONS OF THE AUDITORY NERVE.
(Diagram founded on drawings by Edinger and Ferrier and Turner.)

The **vestibular nerve** enters the brain at a slightly higher level than the cochlear nerve and on the mesial aspect of the ventral cochlear nucleus. It forces its way backwards through the pons between the restiform body, which lies on its outer side, and the spinal root of the

fifth nerve, which is placed on its inner side. Its fibres come to an end in three nuclei of termination, which are situated in the dorsal part of the pons and medulla, viz. (1) the principal nucleus or dorsal nucleus; (2) the nucleus of the descending root; and (3) the nucleus of Deiters.

The **principal nucleus** (Figs. 334, p. 463, and 357, p. 480) is a large diffuse nuclear mass, which lies in the floor of the fourth ventricle subjacent to the surface district known as the *area acustica*. It is situated, therefore, in both the pons and the medulla to the outer side of the fovea superior and the fovea inferior. In section it is prismatic in outline, and crossing its surface immediately under the ependyma of the ventricle are the striæ acusticæ.

When the nervus vestibularis, as it traverses the brain, reaches the inner aspect of the dorsal portion of the restiform body, a very large proportion of its fibres turn vertically downwards in separate bundles and form the descending root of the vestibular nerve (Figs. 341, p. 458; 343, p. 460; 344, p. 463; 357, p. 480). This proceeds through the lower part of the pons into the medulla, in which it may be traced as far as the level of the decussation of the fillet. Associated with the descending root there is a column of gray matter, with nerve-cells strewn sparsely throughout it. This is the **nucleus of the descending root**, and the fibres end in fine arborisations around these nerve-cells.

The fibres of the vestibular nerve end mainly in the **nucleus of Deiters**. This nucleus is composed of a number of large and conspicuous multipolar nerve-cells, which are scattered amidst the bundles of the descending root of the vestibular nerve. As it is traced upwards into the pons the nucleus gradually inclines backwards, and finally it occupies a place in the lateral wall of the fourth ventricle. It attains its greatest development at the level of the emerging part of the facial nerve, and this upper part is sometimes termed the **nucleus of Bechterew**.

Central Connexions of the Cochlear Nerve.—The cochlear nerve is brought into connexion with the inferior quadrigeminal body, and the corpus geniculatum internum of the opposite side by the fibres of the corpus trapezoides and the lateral fillet. But this connection is not direct; the chain is composed of several separate links or neurons superimposed one over the other.

The fibres of the cochlear nerve end in the ventral cochlear nucleus and in the tuberculum acusticum. From the cells of these nuclei two tracts arise, viz. a **ventral tract**, composed of the fibres of the corpus trapezoides, and a **dorsal tract**, which is represented by the striæ acusticæ.

The **corpus trapezoides** (Figs. 357 and 358) is formed of the axons of the cells of the ventral cochlear nucleus, as well as certain of the axons of the cells of tuberculum acusticum. Many of these fibres end in the superior olive, whilst others are added to the tract from the cells of that nuclear mass. So constituted, the trapezial fibres cross the mesial plane and decussate with the corresponding fibres of the opposite side. Reaching the opposite superior olivary nucleus a further interchange of fibres takes place, and almost immediately after this the strand turns upwards and becomes the **lateral fillet** (Figs. 346, p. 466; 347, p. 467). But still another nucleus is interposed in its path, viz. the **nucleus of the lateral fillet**. Here some fibres are dropped, whilst from the nuclear cells others are acquired, and the lateral fillet then proceeds onwards without further interruption until it reaches the inferior quadrigeminal body and the corpus geniculatum internum, in which its fibres end. It is probable, however, that some likewise extend nto the superior quadrigeminal body.

But the lateral fillet also includes the fibres of the **striæ acusticæ** of the opposite side. These fibres arise from the cells of the tuberculum acusticum, and arrange themselves in the conspicuous bundles which sweep round the dorsal aspect of the restiform body and proceed inwards across the floor of the fourth ventricle, immediately beneath the ependyma (Fig. 333, p. 447). Reaching the middle line they dip forwards into the substance of the medulla, and, crossing the mesial plane, they join the lateral fillet.

It is well to remember that the connexion between the terminal cochlear nuclei and the inferior quadrigeminal body is not altogether with that of the opposite side, as the foregoing description and the diagram (Fig. 357) might lead one to infer. A few fibres pass directly to the inferior quadrigeminal body of the same side, but none to the corresponding corpus geniculatum internum; the connexion with the latter is entirely *crossed* (Ferrier and Turner).

From the corpus geniculatum internum there proceeds a tract to the gray cortex of the superior convolution of the temporal lobe. The whole nervous apparatus is thus linked on to the cerebral cortex, and the succession of neurons which build up the entire chain are therefore: (1) the bipolar cells of the ganglion spirale; (2) the neurons of the terminal cochlear nuclei; (3) the neurons of the superior olive and the nucleus of the lateral fillet; (4) the neurons of the corpus geniculatum internum.

It must be borne in mind that all the axons of the cells of the superior olive do not join the trapezoid strand. Many leave its dorsal aspect and pass backwards in a group called the **pedicle of the superior olive**, to end in the nucleus of the sixth nerve, and, through the posterior longitudinal bundle, in the nuclei of the fourth and third nerves. In this way the organ of hearing is brought into connexion with the nuclei, which preside over the movements of the eyeballs (Figs. 344, p. 463, and 359, p. 484).

Central Connexions of the Vestibular Nerve.—Although the central connexions of the vestibular nerve have been closely studied by many observers, they are still very far from being fully understood. The principal nucleus and the nucleus of Deiters both stand in intimate relation with the superior vermis of the cerebellum; and in consideration of the fact that the vestibular nerve is the nerve of equilibration, this is an important and significant circumstance. The strand which establishes this connexion is termed by Edinger "the direct sensory cerebellar tract," and in all probability it is an efferent tract from the cerebellum. Its fibres arise to a large extent in the cerebellar **roof nuclei** of the opposite side, and, crossing the mesial plane, they sweep forwards around the outer side of the superior cerebellar peduncle to end in the nucleus of Deiters, the chief vestibular nucleus, and very possibly also in the terminal sensory nuclei of certain other cranial nerves, such as the trigeminal, vagus, and glosso-pharyngeal.

Until the precise nature of the nucleus of Deiters is discovered, the exact character of the central connexions of the vestibular nerve will remain more or less obscure. It cannot be regarded as a nucleus specially given over to the vestibular nerve. Composed of large cells scattered amidst the bundles of the descending root of the vestibular nerve, it only becomes a compact nucleus above the level of that nerve, viz. at the point where the restiform body turns backwards into the cerebellum, or, in other words, at the level of the emerging facial nerve and the lower end of the abducent nucleus. Here, in the outer part of the floor of the fourth ventricle, its cells are gathered together in a crowded mass. Deiters himself considered that this nucleus should be regarded as an internode between the cerebellum and the spinal cord, and Ferrier and Turner have brought forward strong evidence in support of this view. Klimoff attaches a very high importance to the direct "sensory" tract of Edinger. From his description, it would appear that he regards it as the only cerebellar efferent tract which takes a downward direction. He believes, further, that the axons of the cells of Deiters form the anterior marginal tract of Lowenthal, which descends in the antero-lateral column of the cord as far as the lumbar region. It is supposed that the fibres of this tract end in the cord in arborescent terminations around the motor cells in the ventral horn of gray matter. Opinion is also divided as to the composition and nature of the so-called descending root of the vestibular nerve. After division of the eighth nerve, Ferrier and Turner were unable to detect any degeneration in this root, and they therefore are inclined to call in question its direct continuity with the nerve. They consider that in all probability it forms an internuncial connexion between the nucleus of Deiters and the cuneate nucleus, in which Bruce has seen its lower end to terminate.

Facial Nerve (nervus facialis) (Figs. 358 and 359).—The facial nerve is composed of two distinct parts, viz. a large efferent or motor portion, the **facial nerve proper**, and a small afferent sensory portion termed the **pars intermedia of Wrisberg.** The facial nerve emerges from the brain at the lower border of the pons, immediately in front and to the inner side of the auditory nerve, whilst the pars intermedia sinks into the upper part of the medulla between the facial and auditory nerves. The three nerves, therefore, lie in intimate relation with each other, where they are attached to the surface of the brain, and they pass in company into the internal auditory meatus.

The **nucleus of origin of the facial nerve** is an oval mass of gray matter, about five mm. in length, and containing numerous groups of large multipolar cells. It is sunk deeply in the dorsal or tegmental part of the lower portion of the pons Varolii, and is placed close to the inner side of the spinal root of the fifth nerve. When transverse sections are made through the brain-stem, the facial nucleus is

encountered the moment the boundary line between the medulla and pons is passed, and the region immediately above the inferior olivary nucleus is reached. At first it lies so deeply in the tegmentum of the pons that it actually rests upon the dorsal aspect of the corpus trapezoides; but a little farther up the superior olive comes into view, and insinuates itself between the facial nucleus and the trapezial fibres. The upper part of the nucleus is in this way tilted somewhat backwards, and thus comes to lie on the dorsal and outer aspect of the superior olive.

The facial nucleus is situated close to the place where the nerve emerges from the brain, but the nerve does not at once pass to this point of exit. It pursues a long and devious path within the pons before it finally reaches the surface. This intrapontine part of the nerve may be divided into three parts, viz.: (1) a radicular part, (2) an ascending portion, and (3) an emergent part.

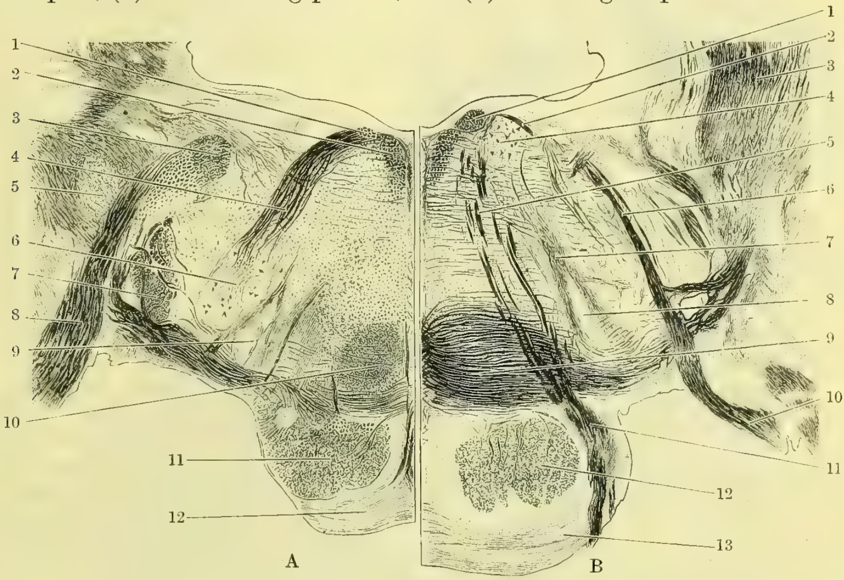


Fig. 358.—Section through the Pons Varolii of the Orang,
Showing the nucleus and intrapontine course of the facial nerve. The left side of the drawing is taken from a section at a slightly lower level than the section from which the right side is taken.

A

1. Ascending part of facial nerve.
2. Posterior longitudinal bundle.
3. Descending root of eighth nerve.
4. Radicular fibres of facial nerve.
5. Restiform body.
6. Facial nucleus.
7. Spinal root of fifth nerve.
8. Vestibular nerve.
9. Superior olive.
10. Fillet.
11. Pyramidal tract.
12. Transverse fibres of pons.

B

1. Ascending part of facial nerve.
2. Emergent portion of facial nerve.
3. Restiform body.
4. Nucleus of sixth nerve.
5. Sixth nerve.
6. Emergent part of facial nerve.
7. Peduncle of superior olive.
8. Superior olive.
9. Corpus trapezoides.
10. Facial nerve.
11. Sixth nerve.
12. Pyramidal tract.
13. Transverse fibres of pons.

The **radicular part of the facial nerve** (Fig. 359) is composed of a large number of fine loosely-arranged bundles of fibres, which issue from the outer and dorsal aspect of the nucleus and proceed backwards and slightly inwards through the pons. Reaching the floor of the fourth ventricle they curve inwards, and the bundles which lie highest up sweep over the outer and dorsal aspect of the lower part of the nucleus of the sixth nerve. Close to the mesial plane they turn sharply upwards and are collected into a single solid nerve-bundle, which constitutes the **ascending part of the facial nerve** (Figs. 358 and 359). This proceeds vertically upwards immediately beneath the ependyma of the ventricular floor, on the dorsal aspect of the posterior longitudinal bundle, and along the inner side of the sixth or abducent nucleus, for a distance of about five millimetres. Suddenly the nerve bends outwards at a right angle and curves a second time over the dorsal aspect of the sixth or abducent nucleus. The nerve now passes straight to the place of exit from the brain, and this part of the intrapontine trunk may be termed the

emergent portion (Figs. 358 and 359). The facial nerve thus forms a curved loop over the dorsal aspect of the abducent nucleus. The **emergent part** of the nerve takes an oblique course through the pons to reach the surface. It inclines outwards and downwards as it proceeds towards the ventral aspect of the pons, and on its way it passes between its own nucleus and the spinal root of the fifth nerve.

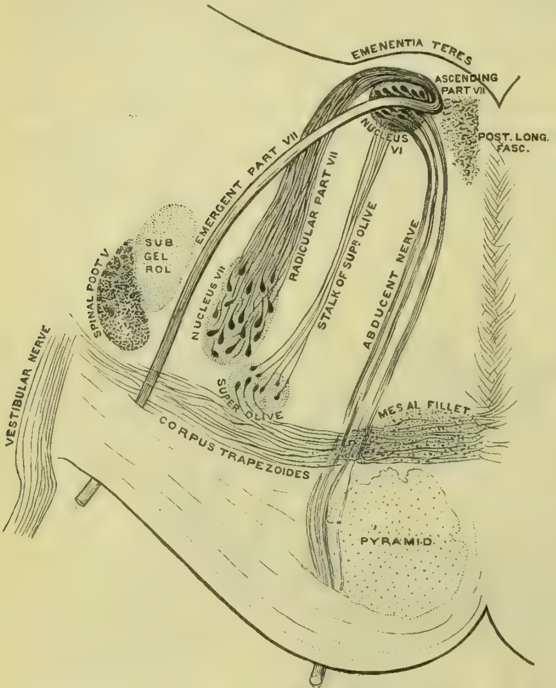


Fig. 359.—Diagram of the Intrapontine Course pursued by the Facial Nerve.

Entering the facial nucleus, and ending in fine terminal arborisations around its cells, are many fibres from the opposite pyramidal tract; fibres from the spinal root of the fifth nerve; fibres from the corpus trapezoides, etc. The nucleus is thus brought into connexion with the motor area of the cerebral cortex, with the trigeminal nerve or sensory nerve of the face, and with the auditory nerve, etc.

The fibres of the **pars intermedia of Wrisberg** arise from the cells of the geniculate ganglion of the facial nerve. These, like the cells of a spinal ganglion, are unipolar, the single process in each case dividing into a peripheral and a central branch. The group of peripheral fibres represent the chorda tympani branch of the facial nerve, whilst the central fibres form the pars intermedia. The latter penetrate the brain, and, passing either through or on the dorsal side of the spinal root of the fifth nerve, they finally reach the upper part of the column of gray matter in connexion with the fasciculus solitarius, and in this they end. The pars intermedia presents, therefore, the same terminal connexions within the brain as the glosso-pharyngeal nerve.

Abducent or Sixth Nerve (nervus abducens) (Figs. 358 and 359).—This is a small motor nerve, which emerges from the brain at the lower border of the pons on the outer side of the pyramid of the medulla. It is the nerve of supply to the external rectus muscle of the eyeball. Its nucleus of origin is a small spherical mass of gray matter, containing large multipolar cells, which lies in the dorsal part of the tegmental portion of the pons, close to the mesial plane and immediately subjacent to the gray matter of the floor of the fourth ventricle. Its position can be easily indicated on the ventricular floor, seeing that it is placed subjacent to the emenentia teres and immediately above the level of the striæ acusticæ. Its peculiar and intimate relation to the intrapontine portion of the facial nerve has already been indicated. It lies on the ventral aspect of, and within the concavity formed by, the two limbs of the loop of that nerve.

The axons of the multipolar cells of this nucleus emerge from the inner aspect of the nucleus in the form of several bundles, which proceed through the whole antero-posterior thickness of the pons towards the place of exit. In this course they incline downwards and slightly outwards as they pass forwards. In the tegmental part of the pons they proceed forwards on the inner side of the superior olive, whilst in the ventral part of the pons they keep for the most part to the outer side of the pyramidal bundles, although several of the nerve fasciculi pierce these on their way to the surface.

It would appear probable that certain of the axons of the cells of the abducent nucleus enter the posterior longitudinal fasciculus and proceed upwards in it to join the third or oculomotor nerve of the opposite side. Further mention of these will be made later on. Fibres

and collaterals from the pyramidal tract of the opposite side enter the nucleus, and, ending around the cells, bring the nucleus into connexion with the motor area of the cerebral cortex. The pedicle of the superior olive ends partly within the nucleus of the abducent nerve (p. 482).

Trigeminal or Fifth Nerve (nervus trigeminus).—The trigeminal nerve strikes its roots deeply into the brain and establishes a connexion with it which extends from the upper part of the mesencephalon above to the level of the second cervical nerve below. No other cranial nerve presents so extensive a connexion (Fig. 356, p. 479). It is composed of two roots—a large afferent or sensory root and a small efferent or motor root. Both roots appear close together on the surface of the pons, rather nearer its upper border than its lower border, and in the same line as the facial and auditory nerves.

The **sensory root of the fifth nerve** is composed of fibres which arise outside the brain from the cells of the Gasserian ganglion. They end within the brain in two

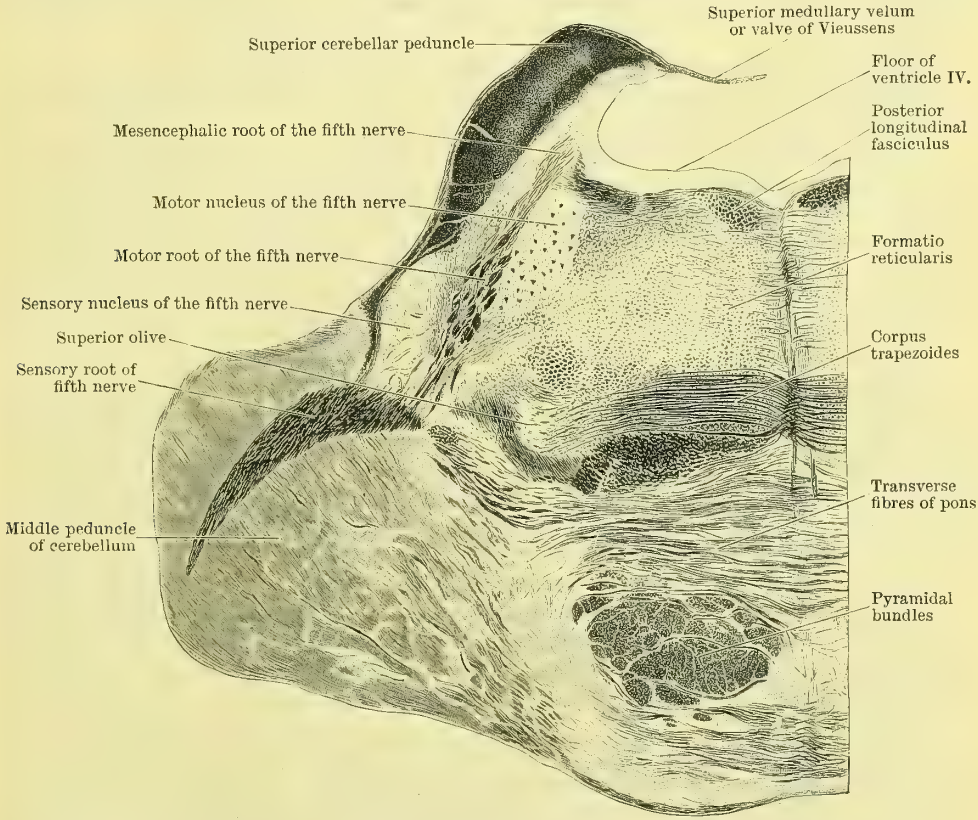


Fig. 360.—Section through the Pons Varolii of the Orang, at the Level of the Nuclei of the Trigeminal Nerve.

nuclei of termination. One of these is situated in the pons and is termed the sensory nucleus of the trigeminal nerve, and the other is a long column of gelatinous gray matter, which is directly continuous below with the substantia gelatinosa Rolandi of the spinal cord.

The **sensory nucleus** (Fig. 360) is an oval mass of gray matter which is placed halfway up the pons in the outer part of its tegmental portion. It lies close to the outer surface of the pons and immediately subjacent to the ventral submerged margin of the superior cerebellar peduncle. It is directly continuous with the substantia gelatinosa Rolandi, and may be regarded as being merely the enlarged upper end of that column of gray matter.

The sensory root of the fifth nerve, on reaching the sensory nucleus, divides into two parts (Fig. 356, p. 479). A portion of the fibres enter that nucleus and end within it, but the great proportion of the fibres turn sharply downwards and form the **spinal root** (tractus spinalis: the ascending root of most text-books). This root

descends on the outer side of the column of gray matter formed by the substantia gelatinosa Rolandi, which constitutes its terminal nucleus. Fibres constantly leave it to enter the nucleus, so that the lower it gets the smaller does the spinal root become until, in the upper part of the spinal cord about the level of the first or second spinal nerve, it disappears altogether.

The large spinal root of the fifth nerve is a conspicuous object in sections through the pons and medulla. In the former it traverses the tegmental part, first, between the emergent part of the facial nerve and the vestibular nerve; and then lower down, between the restiform body and the nucleus of the facial nerve (Fig. 358, A, p. 483). In cross sections it presents a well-defined semilunar or curved pyriform outline. In the upper part of the medulla, it lies on the ventral aspect of the restiform body and nearer to the surface (Fig. 341, p. 458). Here it is traversed and broken up into separate bundles by the cerebello-olivary fibres and the roots of the glosso-pharyngeal and vagus nerves. Finally, it comes to the surface and its fibres are spread over the area on the side of the medulla known as the tubercle and funiculus of Rolando (Fig. 338, p. 455).

The small **motor part of the trigeminal nerve** is chiefly distributed to the muscles of mastication and derives its fibres from two sources, viz. from the motor nucleus and from the mesencephalic root of the trigeminal nerve.

The **motor nucleus** (Fig. 360) lies in the lateral part of the tegmental portion of the pons, close to the inner side of the sensory terminal nucleus, but somewhat nearer to the floor of the fourth ventricle. It is not placed in the exact line of the facial nucleus, as it is situated somewhat nearer the dorsal aspect of the pons; but, nevertheless, it may be considered as being equivalent in this region to the detached head of the anterior horn of gray matter in the lower part of the medulla. The cells of this nucleus are large and multipolar, and their axons run together to form the motor part of the fifth nerve.

The **mesencephalic root** takes origin in the mesencephalon from a column of large loosely-arranged cells which are placed in the extreme lateral part of the gray matter which surrounds the Sylvian aqueduct. As this root is traced downwards it gradually gains strength by the addition of new fibres, and it assumes a crescentic form in transverse section (Figs. 365, p. 494; 367, p. 496; 347, p. 467; 346, p. 466). In the lower part of the mesencephalon it lies on the inner side of the superior cerebellar peduncle; and the fourth nerve, on its way to the surface, runs downwards in its concavity and on its mesial aspect. In the upper part of the pons, it continues its course downwards on the outer and deep aspect of the gray matter which forms the floor of the fourth ventricle. Finally, reaching the level of the nuclei of the trigeminal nerve, the fibres of the mesencephalic root turn forwards and join the motor part of the trigeminal nerve.

(1) It is not known to what parts the fibres of the mesencephalic root go. Kölliker suggests that they supply the tensor veli palatini and the tensor tympani; perhaps, also, they may be distributed to the mylo-hyoid and the anterior belly of the digastric. (2) Fibres from the opposite pyramidal tract go to the motor nucleus and bring it into connexion with the motor area of the cerebral cortex. (3) By degeneration methods the root of the fifth nerve has been traced down to the level of the second cervical nerve (Ferrier and Turner). (4) Many of the axons of the terminal nuclei emerge as arcuate fibres, and, proceeding through the raphe, assume a longitudinal course in the fillet of the opposite side, and thus establish connexions with parts higher up. (5) Some of the axons of the cells of the terminal nucleus enter the motor nucleus, and thus establish a simple reflex apparatus.

The Development of the Parts derived from the Rhombencephalon.

A general sketch of the development of the medulla, pons, and cerebellum has already been given (p. 441). It is only necessary, therefore, in this section to call attention to some of the more important details connected with the process.

Medulla.—In the embryo the cervical flexure indicates in a sharp and definite manner the point of junction between the cord and the brain (Fig. 327, p. 441). In the early condition of the rhombencephalon the calamus scriptorius extends downwards to this level, so that, in the first instance, there is no part of the medulla which corresponds to the closed portion present in the adult. The lower closed part of the medulla makes its appearance at a later period, and is termed by His the **intercalated portion** (Schaltstück).

In our study of the development of that part of the neural tube which forms the spinal

cord we have recognised two thick lateral walls connected in front and behind by narrow mid-ventral and mid-dorsal laminæ. The same parts are seen in the developing medulla. Owing, however, to the expansion of the cavity in this portion of the tube the mid-dorsal lamina is stretched out into an extensive and thin epithelial membrane, which forms the dorsal wall or roof of the ventricle at this level. The thick lateral walls have also fallen away from each other, and are joined in front by the narrow mid-ventral lamina. On section, therefore, the medullary part of the neural tube presents a triangular figure—the base, which is directed backwards, being formed by the thin epithelial expansion derived from the mid-dorsal lamina, the apex by the narrow mid-ventral lamina, and the sides by the thick lateral walls of the tube. Further, each lateral wall consists of an alar or dorsal and a basal or ventral lamina. This subdivision is more clearly indicated than in the cord, and on the inner surface of the lateral wall a strongly-marked longitudinal furrow marks the line of junction of the two laminæ. The histological development of these several parts of the wall of the medullary portion of the neural tube proceeds in a manner very similar to that already detailed in the case of the cord. No neuroblasts are formed in the mid-ventral and mid-dorsal laminæ; the entire neuroblastic formation is confined to the basal and alar laminæ. Within the basal lamina, likewise, are collected the neuroblasts which form the nuclei of origin of the efferent nerves; whilst within the alar lamina are developed the neuroblasts which constitute the nuclei of termination for the fibres of the afferent nerves.

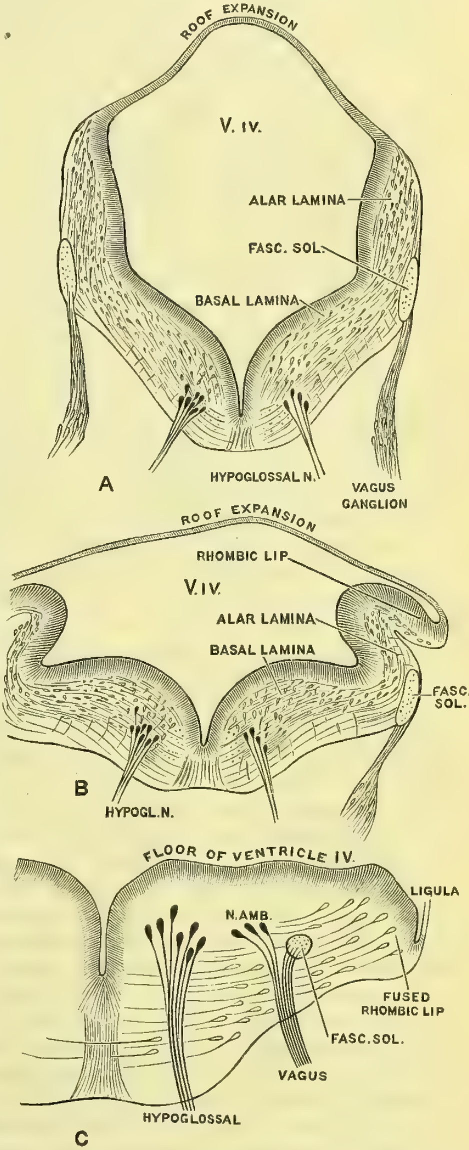


Fig. 361.—Three Stages in the Development of the Medulla Oblongata (from His—slightly modified).

As development proceeds, the two laminæ of the lateral wall fall outwards to a still greater extent, so that they come to lie very nearly in the same horizontal plane. In this manner their originally mesial or ventricular surfaces come to form the floor of the fourth ventricle. Even in the adult the groove, which separates the basal and alar laminæ so clearly from each other in the early condition, is more or less distinctly perceptible on the ventricular floor. It is represented by the fovea inferior and by the fovea superior. Between these depressions and the mesial groove on the floor of the fully-developed fourth ventricle there is an elongated elevation, which, in its lower part, forms the trigonum hypoglossi, above this the emenentia teres, whilst higher up it is continued towards the commencement of the Sylvian aqueduct. This clearly-marked and bulging mesial strip of the ventricular floor corresponds to the basal lamina, whilst the part of the floor which lies to the outer side of it and the two foveæ is derived from the alar lamina. The latter, therefore, includes the trigonum vagi, the area acustica, and the locus cœruleus.

The further development of the medulla takes place on the ventral aspect of the two laminæ by the deposition of new parts on those which are already formed. An oval bundle of longitudinal fibres makes its appearance on the outer surface of the alar lamina, at the point where this joins the basal lamina. This is the early fasciculus solitarius. It is composed of afferent fibres from the glosso-pharyngeal and vagus nerves. These, on reaching the surface of the medulla, turn downwards upon it. At first the

connexion of the fasciculus solitarius with the medulla is very loose, and it may be regarded as being the equivalent in this part of the neural tube of the oval bundle of longitudinal fibres which, in the early cord, constitutes the first stage of the column of Burdach. Throughout the further stages of development the fasciculus solitarius indicates in a sufficiently clear manner the point of junction between the alar and basal laminæ. Very soon it becomes covered over by parts developed on its ventral aspect, and it ultimately comes to lie deeply in the substance of the medulla. This change in the position of the fasciculus solitarius with reference to the surface is associated with a striking developmental process which leads to certain remarkable results, and which is termed the formation of the **rhombic lip** of His (Fig. 361, B and C). Before the alar lamina falls outwards, while it still stands erect and its inner surface faces the corresponding surface of the opposite lamina, its dorsal edge is folded outwards and becomes fused with the outer surface of the remaining portion of the alar lamina. This is the rhombic lip, and, when the fusion is complete, a multitude of neuroblasts take form within it and migrate in a forward and inwards direction into the ventral parts of the alar and basal laminæ. The mid-ventral lamina—which consists of spongioblastic cells alone and which forms a narrow partition between the two basal laminæ—is reached on either side by the axons of many of these migrating cells. Whilst acting as an impassable barrier to the neuroblasts, this spongioblastic septum gives free passage from one side to the other to their axons, and a decussation of arcuate fibres in the mesial plane results. In this way the raphe of the medulla is formed. The process is very similar to that which takes place in the course of the formation of the anterior commissure of the cord, of which the raphe may be regarded as the equivalent in the medulla.

The development of the inferior olivary nucleus and of its two accessory parts is likewise closely connected with the migration of the neuroblasts from the region of the rhombic lip. Many of these cells collect together so as to form a nuclear lamella, which afterwards assumes its characteristic crumpled form.

As the neuroblasts of the rhombic lip stream inwards they pass both on the dorsal and the ventral aspects of the fasciculus solitarius, which thus comes to be covered over and separated from the surface. The spinal root of the trigeminal nerve, like the fasciculus solitarius, is also, in the first instance, throughout its entire course on the surface of the medulla, and its change of position in the greater part of its course within the pons and medulla is due to the subsequent development of those parts which cover it over.

The importance of the rhombic lip in the development of the medulla will be better appreciated if we enumerate the parts which spring from it: (1) the inferior olivary nuclei; (2) the cuneate nucleus; (3) the substantia gelatinosa Rolandi; (4) the arcuate nucleus; (5) the internal arcuate fibres; (6) the olivary system of fibres; (7) the restiform body.

The pyramidal tracts which come down from the cerebral cortex are late in making their appearance in the medulla. The formatio reticularis precedes them in development. They appear in the fourth month of fœtal life, and as they are developed the antero-median furrow between them takes form on the ventral aspect of the medulla.

His has pointed out that the earliest-formed part of the medulla is the floor of the fourth ventricle, and that the other parts, speaking generally, are added in succession as we pass towards the surface. "The oldest layer of the medulla is the floor of the fourth ventricle with its nuclei. It is followed, in the first instance, by the reticular formation, and afterwards by the layer containing the olivary and other nuclei. Last of all come the pyramids and the outer (superficial) arcuate fibres" (His).

Pons Varolii.—The information which we possess at the present moment regarding the development of the pons Varolii is somewhat deficient; but there is little doubt that the course pursued is, in general, very similar to that which has been described for the medulla. It has been seen to be composed of parts which are in a great measure equivalent to those met with in the medulla, the formatio reticularis of the latter passing into the tegmental substance in the former, while the pyramids and arcuate nuclei and anterior superficial arcuate fibres of the medulla are represented by the large ventral part of the pons. Further, as His points out, similar relations between the chronological and local succession of layers may be recognised. Thus the primitive position of the motor nucleus of the trigeminal nerve, and also of its spinal root, is a superficial one, and it is only by a later process of development that the nucleus pontis and the thick layer of transverse and longitudinal fibres are formed.

Cerebellum.—The following account of the development of the cerebellum is framed largely upon the information supplied in an excellent paper on the subject by Dr. Walther Kuithan.

The roof of the fourth ventricle is formed for the most part by the thin epithelial layer already described as being formed by the expanded mid-dorsal lamina. This does not stretch, however, over its entire extent. As we approach the upper part of the ventricle, it is seen to become continuous in the region of the isthmus with a thicker lamella. This lamella is bounded *above* by the intercrossing of the two trochlear nerves, which marks on the dorsal aspect of the neural tube the place of junction between the rhombencephalon and the mesencephalon; *below*, it is limited by a forwardly-directed semilunar fold of the thin epithelial ventricular roof, which takes place into the ventricular cavity at the level of the pontine flexure of the brain. The fold so constituted is termed the plica choroidea, seeing that mesoderm is introduced between its two layers, and this ultimately gives rise to the choroid plexus of the fourth ventricle (Fig. 362, D). The lamella which forms the roof or dorsal wall of the ventricle in front of the plica choroidea is developed into the inferior medullary velum, the cerebellum, and the superior medullary velum (valve of Vieussens).

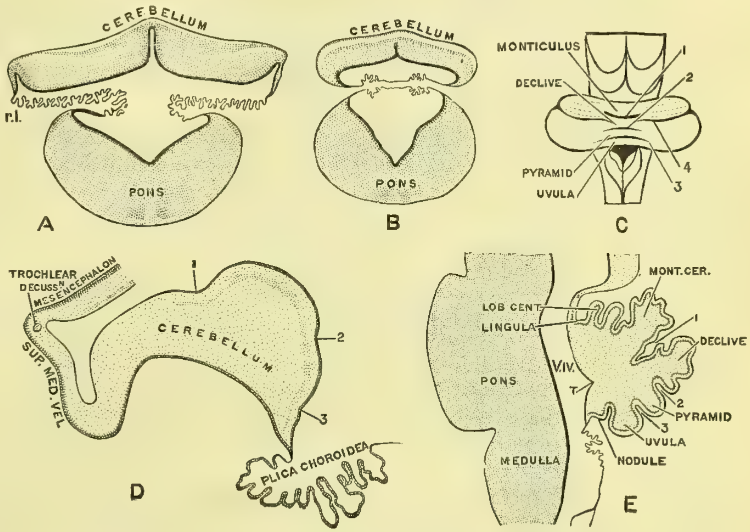


FIG. 362.—FROM DRAWINGS BY DR. WALTHER KUITHAN, TO ILLUSTRATE THE DEVELOPMENT OF THE CEREBELLUM.

A. Transverse section through the forepart of the cerebellum of a sheep embryo.
B. Transverse section through the hinder part of the cerebellum of a sheep embryo.
C. Cerebellum of a human fœtus 17 cm. long.
D. Median section through the cerebellum of a sheep embryo 5 cm. long.
E. Median section through cerebellum of human fœtus 17 cm. long.

1. Sulcus primarius.
2. Sulcus above and afterwards behind the pyramid.
3. Sulcus between pyramid and uvula.
4. Great horizontal fissure.

r.l. Lateral recess ventricle IV.
T. Transverse groove in roof of ventricle IV.

The cerebellar portion of this lamella in mesial sections through the brain is soon strongly demarcated from the medullary vela by the great thickening it undergoes in a dorsal direction. At first the thickened cerebellar lamella forms a simple uniform arch around the dorsal aspect of the upper part of the fourth ventricle. In a short time, however, it becomes thinner along the median plane, whilst it increases in bulk on either side (Fig. 362, A). As a result of this, the cerebellum is now seen to consist of two thick plates joined by a narrow and thin median portion. This bilateral condition of the organ is transitory. In the further course of development the two plates fuse completely in the middle line (Fig. 362, B), and sulci then begin to make their appearance on the dorsal aspect of the organ.

The sulci which come earliest into view are limited to the region of the worm. The first sulcus appears between the regions corresponding to the monticulus cerebelli and the clivus cerebelli, and in the adult cerebellum this may be seen to be the deepest of all the fissures of the vermiform process. It may be termed the **sulcus primarius** (Fig. 362, C, D, E). The portion of the vermis which lies below this fissure soon shows other sulci. One appears above the region of the pyramid, another between the pyramid and uvula, whilst a third marks off the nodule. All this time the portion of the vermis above the sulcus primarius remains more or less smooth, but very soon it becomes divided up into its constituent parts. The earliest sulcus to appear in the lateral hemisphere is the **great horizontal sulcus** (Fig. 362, C). This at first consists of separate portions in the two hemispheres, and it is only in the later months of development that these run together over the vermis, so as to separate the tuber valvulæ from the declive monticuli. Even at the time of birth the folium cacuminis is not seen on the surface. It rises up from the bottom of the horizontal sulcus in the form of a secondary folium of the declive monticuli.

Very early a transverse groove appears on the smooth anterior or ventricular surface

of the cerebellum (Fig. 362, E, T.). This is placed much nearer the lower than the upper border of the organ, and it represents at this stage the angular peak of the tent-like roof of the fourth ventricle in the adult brain. As growth goes on, the portions of the cerebellum in front and behind this groove approach each other, so as to deepen the groove and bring about the backward prolongation of the ventricular cavity towards the cerebellum.

THE MESENCEPHALON.

The mesencephalon or mid-brain is the short, narrow part of the brain-stem which occupies the aperture of the tentorium cerebelli (incisura tentorii), and connects the cerebrum which lies above with the parts which occupy the posterior cranial fossa. It is about three-quarters of an inch in length, and it consists of a dorsal part, composed of the **corpora quadrigemina**, and a much larger ventral part, which is formed by the two **crura cerebri**.

In the undissected brain the corpora quadrigemina are completely hidden from view by the splenium of the corpus callosum, which projects backwards over them, and also by the superimposed cerebral hemispheres. The hinder end of each optic thalamus likewise, to some extent, overhangs the upper part of the mesencephalon on its dorsal and lateral aspect (Fig. 333, p. 447). On this portion of the optic thalamus are seen two projections, which are specially related to the mesencephalon. These are the cushion-like **pulvinar**, which forms the inner and hinder part of the thalamus, and the **corpus geniculatum externum**, an ill-defined oval swelling on the outer and under aspect of the posterior end of the thalamus.

The crura cerebri can to some extent be seen on the base of the brain, where they bound the posterior part of the interpeduncular space. Encircling the upper end of each crus cerebri, where it plunges into the cerebrum, is the optic tract (Fig. 325, p. 439).

The mesencephalon is tunnelled from below upwards by a narrow passage, called the aqueduct of Sylvius, which connects the fourth ventricle with the third ventricle (Fig. 364, p. 492). This channel lies much nearer the dorsal than the ventral aspect of the mesencephalon.

Corpora Quadrigemina.—This name is applied to four rounded eminences on the posterior aspect of the mesencephalon (Fig. 333, p. 447). The **superior pair** are larger and broader than the **inferior pair**, but they are not so well defined nor are they so prominent. A longitudinal and a transverse groove separate the quadrigeminal bodies from each other. The longitudinal groove occupies the mesial plane and extends upwards to the posterior commissure of the brain. The upper end of this groove widens out into a shallow depression, in which the **pineal body**, a small conical structure which belongs to the diencephalon, rests. From the lower end of the same groove a short but well-defined and projecting band of white fibres, the **frenulum veli**, passes to the valve of Vieussens, which lies immediately below the inferior pair of quadrigeminal bodies. The transverse groove curves round behind each of the superior pair of quadrigeminal bodies and separates them from the inferior pair. It is also continued in an upward and forward direction on the lateral aspect of the mesencephalon.

The quadrigeminal bodies are not marked off laterally from the sides of the mesencephalon, but each has in connexion with it, on this aspect, a prominent strand of white matter, which is prolonged upwards and forwards under the projecting pulvinar and corpus geniculatum externum. These strands are called the **brachia of the corpora quadrigemina**, and they are separated from each other by a continuation on the side of the mesencephalon of the transverse groove, which intervenes between the two pairs of bodies.

The **corpus geniculatum internum** (corpus geniculatum mediale) is closely associated with the brachia. It is a small, sharply-defined oval eminence, which lies on the side of the upper part of the mesencephalon under shelter of the pulvinar of the optic thalamus.

The **inferior brachium** (brachium quadrigeminum inferius), proceeding upwards from the lower quadrigeminal body, advances towards the corpus geniculatum internum and disappears from view under cover of this prominence. Upon the

opposite side of the same geniculate body the mesial root of origin of the optic tract takes shape on the surface, and the appearance is such that the conclusion might very naturally be arrived at that the inferior brachium and this root of the optic tract are continuous with each other under the geniculate elevation. This is not the case, however; the fibres of the inferior brachium, to a large extent, proceed into the subjacent tegmentum under cover of the internal geniculate body and help to constitute an ascending tract from the inferior quadrigeminal body, which proceeds upwards to the optic thalamus. Of the fibres of the mesial root of the optic tract some end in the gray matter of the internal geniculate body, whilst others arise within it. They constitute what is called **Gudden's commissure.**

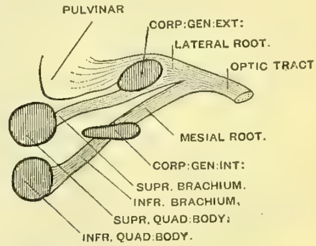


Fig. 363.—Diagram of the Roots of the Optic Nerve.

The **superior brachium** (brachium quadrigeminum superius) is carried upwards and forwards between the overhanging pulvinar and the corpus geniculatum internum. A surface examination of the mesencephalon is sufficient to show that, while a large part of this strand enters the corpus geniculatum externum, a considerable portion runs into the lateral root of the optic tract.

The **optic tract** is thus attached to the brain-stem by two roots, viz. a mesial and a lateral, which are separated from each other by a distinct groove. The **mesial root** disappears under the internal geniculate body. The **lateral root** spreads out and some of its fibres enter the superior quadrigeminal body through its brachium, whilst others find their way into the corpus geniculatum externum and the pulvinar of the optic thalamus.

Crura cerebri (pedunculi cerebri).—The crura cerebri constitute the chief bulk of the mesencephalon (Fig. 364, p. 492). Upon the basal aspect of the brain they appear as two large rope-like strands, which emerge close together from the upper aspect of the pons Varolii and diverge as they proceed upwards to enter the cerebrum. At the place where each crus disappears into the corresponding side of the cerebrum, it is encircled by the optic tract.

Each crus cerebri is composed of two parts, viz. a **dorsal tegmental part** (tegmentum), which is prolonged upwards into the region below the optic thalamus (subthalamic tegmental region), and a **ventral pedal portion** or **crusta** (basis pedunculi), which, when traced upwards into the cerebrum, is seen to take up a position on the outer side of the optic thalamus and to be continuous with the internal capsule. When the base of the brain is examined it is the crusta which is seen, and it is observed to be white in colour and streaked in the longitudinal direction. In the tegmentum the longitudinally-arranged fibres are, for the most part, corticipetal, or, in other words, fibres which are ascending towards the cortex of the cerebrum; the crusta, on the other hand, is entirely composed of longitudinal strands of fibres which are corticifugal or fibres which descend from the cortex cerebri.

On the surface of the mesencephalon the separation between the tegmental and pedal portions of the crus cerebri is clearly indicated by an inner and an outer groove. The inner or mesial furrow is the more distinct of the two. It looks into the interpeduncular space, and from it emerge the fascicles of the third or oculo-motor nerve. It is, therefore, termed the **sulcus oculo-motorii** (sulcus nervi oculo-motorii). The outer groove, which is placed on the lateral aspect of the mesencephalon, receives the name of the **sulcus lateralis mesencephali.** When traced downwards, it is observed to become continuous with the furrow which intervenes between the middle and superior peduncles of the cerebellum.

A close inspection of the outer surface of the tegmental part of the crus cerebri, below the level of the quadrigeminal brachia, will reveal some faintly-marked bundles of fibres curving obliquely upwards and backwards to reach the inferior quadrigeminal body (Fig. 335, p. 449). These are fibres of the **lateral fillet**, coming to the surface at the sulcus lateralis and sweeping over the subjacent superior cerebellar peduncle to gain the inferior quadrigeminal body.

INTERNAL STRUCTURE OF THE MESENCEPHALON.

When transverse sections are made through the mesencephalon the aqueduct of Sylvius is seen to be surrounded by a thick layer of gray matter, which receives the name of the **Sylvian gray matter** or the **central gray matter of the aqueduct** (stratum griseum centrale). On the dorsal aspect of the Sylvian gray matter the corpora quadrigemina form a layer which separates it from the surface, and to which the term **lamina quadrigemina** is applied. On the ventral and lateral aspects of the Sylvian gray matter are the tegmental portions of the crura cerebri, whilst, intervening between each of the latter and the corresponding crusta, there is a conspicuous mass of dark pigmented matter termed the **substantia nigra**.

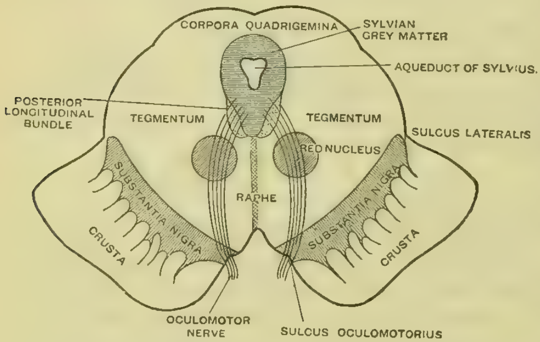


Fig. 364.—Diagrammatic View of the Cut Surface of a Transverse Section through the Upper Part of the Mesencephalon.

Sylvian aqueduct and Sylvian gray matter (aquæductus cerebri—stratum griseum centrale).—The aqueduct of Sylvius is the canal which leads from the fourth ventricle below, upwards through the mesencephalon, to the third ventricle above. It is not quite three-quarters of an inch in length, and it lies much nearer the dorsal than the ventral surface of the mesencephalon. When examined in transverse section, it presents a triangular outline as it passes into the fourth ventricle and a T-shaped outline close to the third ventricle. In the intermediate part of its course it assumes different outlines, and not always the same form at the same level in different individuals.

The aqueduct of Sylvius is lined by ciliated epithelium, and outside this is the thick layer of Sylvian gray matter, which is directly continuous below with the gray matter spread out on the floor of the fourth ventricle, and above with gray matter on the floor and sides of the third ventricle. Scattered more or less irregularly throughout the Sylvian gray matter are numerous nerve-cells of varying forms and sizes, whilst in addition to these there are three definite collections or clusters of cells, which constitute the nuclei of origin of the trochlear nerve, the oculo-motor nerve, and the mesencephalic root of the trigeminal nerve. The position and relations of these will be given at a later stage.

Substantia Nigra.—When seen in transverse section, the substantia nigra presents a semilunar outline. It consists of a mass of gray matter, in the midst of which are large numbers of deeply pigmented nerve-cells. It is only when this substance is examined in bulk that it appears dark; in thin sections it does not differ much in colour from ordinary gray matter, although, under the microscope, the brown-coloured cells stand out very conspicuously, even under low powers. The substantia nigra is, in reality, disposed in the form of a thick band, interposed between the tegmental and pedal portions of the crus cerebri. It begins below at the upper border of the pons Varolii and extends upwards into the subthalamic region. The margins of this band of dark-coloured substance come to the surface at the oculo-motor and the lateral sulci of the mesencephalon, and its inner part is traversed by the emerging fascicles of the oculo-motor nerve. It is not equally thick throughout. Towards the lateral sulcus it becomes thin, whilst it thickens considerably near the inner aspect of the crus cerebri. The surface of the substantia nigra, which is turned towards the tegmentum, is concave and uniform; the opposite surface is convex and rendered irregular by the presence of numerous slender prolongations of the substance into the crusta.

The morphological and physiological significance of the substantia nigra is not fully understood, and the connexions established by its cells are imperfectly known.

Inferior Quadrigeminal Bodies (colliculi inferiores).—Each of the inferior

quadrigeminal bodies is largely composed of a mass of gray matter which, in transverse section, presents an oval outline (Fig. 367, p. 496). This central nucleus is, to a large extent, encapsulated by white matter. Numerous cells of different sizes are scattered throughout it, and the whole mass is pervaded by an intricate interlacement of fine fibres, which are derived from the lateral fillet and the inferior brachium.

In transverse sections, through this region, the lateral fillet is seen to abut against the outer margin of the central nucleus. Many of the fibres of this tract enter it at once and become dispersed amongst its cells; others sweep over its dorsal surface, so as to give it a superficial covering; whilst a third group is carried in the form of a thin layer inwards on its ventral aspect, so as to mark it off from the subjacent Sylvian gray matter of the aqueduct (Fig. 367, p. 496). In this manner, therefore, the inferior quadrigeminal nucleus becomes partially circumscribed by the fibres of the lateral fillet. Several of the lateral fillet fibres, which proceed over the superficial or dorsal aspect of the nucleus, reach the mesial plane and form a loose decussation with the corresponding fibres of the opposite side.

The intimate connexion which is thus exhibited between the fibres of the lateral fillet and the nucleus of the inferior quadrigeminal body is very significant. It has already been shown that the lateral fillet, to a large extent, comes from the nuclei of termination of the cochlear nerve of the opposite side, although most of its fibres have to pass through several nuclear internodes before they reach the inferior quadrigeminal body. We must associate, therefore, the inferior quadrigeminal body, and also the corpus geniculatum internum, which likewise receives lateral fillet fibres, with the organ of hearing.

This view of the inferior quadrigeminal bodies is supported both by experimental and by morphological evidence. Speaking broadly, it may be stated that the inferior quadrigeminal bodies are only present as distinct eminences in mammals, and then they are invariably correlated with a spirally-wound and well-developed cochlea. That they have nothing to do with sight is shown by the fact that, when the eyeballs are extirpated in a young animal, the inferior quadrigeminal bodies remain unaffected, whilst the superior quadrigeminal bodies after a time atrophy (Gudden). When, on the other hand, the cochlear terminal nuclei are destroyed, fibres which have undergone atrophy may be followed to the inferior quadrigeminal bodies of both sides, but particularly to that of the opposite side (Baginski, Bumm, and Ferrier and Turner). A very considerable tract of ascending fibres takes origin within the inferior quadrigeminal body and passes upwards, in the inferior brachium, into the tegmentum subjacent to the internal geniculate body. Within the tegmentum they proceed up to the optic thalamus (Ferrier and Turner).

Superior Quadrigeminal Bodies (colliculi superiores).—The superior quadrigeminal body presents a more complicated structure (Fig. 366). Superficially, it is coated with a layer of white matter, which is termed the **stratum zonale**. Underneath this there is a gray nucleus, called the **stratum cinereum**, which in transverse section exhibits a crescentic outline and rests in a cap-like manner upon the subjacent part of the eminence. The succeeding two strata, which respectively receive the names of **stratum opticum** and the **stratum lemnisci**, present this feature in common that they are composed of gray matter, traversed by numerous fibres. The source from which the fibres are derived differs, however, in each case.

Nerve-fibres reach the superior quadrigeminal body through—(1) the lateral and mesial fillets, and (2) through the superior brachium. The **fillet fibres** enter the stratum lemnisci, and, in all probability, end there. The **superior brachium** contains fibres of two different kinds, viz. fibres from the optic tract and fibres from the cortex of the occipital lobe of the cerebrum. By the former it is connected with the retina, and by the latter with the visual centre in the occipital region of the cerebral cortex. The *retinal fibres*, for the most part, spread out on the surface of the quadrigeminal body and form the stratum zonale. Most of them dip down into the substance of the body and end in connexion with the cells of the deeper layers; several, however, are carried across the mesial plane, to end in the superior quadrigeminal body of the opposite side. The *occipital fibres*, and probably also some of the retinal fibres, enter the stratum opticum. The fibres from the occipital cortex form part of the optic radiation, and the course which they pursue will be dealt with later on.

Tegmental Portions of the Crura Cerebri (tegmenta).—The tegmentum of the crus cerebri may be regarded as the continuation upwards of the formatio

reticularis of the medulla and the dorsal or tegmental portion of the pons into the mesencephalon. It therefore consists of fine bundles of longitudinal fibres intersected by arching fibres, which take a transverse and curved course. The interstices between these nerve-bundles is occupied by gray matter containing irregularly scattered nerve-cells. On its dorsal aspect the tegmentum is continuous, at the side of the Sylvian gray matter, with the bases of the corpora quadrigemina, whilst ventrally it is separated from the crusta by the substantia nigra. The two tegmenta of opposite sides are, to some extent, marked off from each other in the mesial plane by a prolongation upwards of the median raphe of the pons and medulla, although, in the lower part of the mesencephalon, this is much obscured by the decussation of the superior peduncles of the cerebellum. The two longitudinal strands, termed the **posterior longitudinal bundle** and the **fillet**, are prolonged upwards throughout the entire length of the mesencephalon; and they present the same relations to the tegmentum as in the lower parts of the brain. The former is placed in relation to its dorsal aspect, whilst the fillet is carried up in its ventral part.

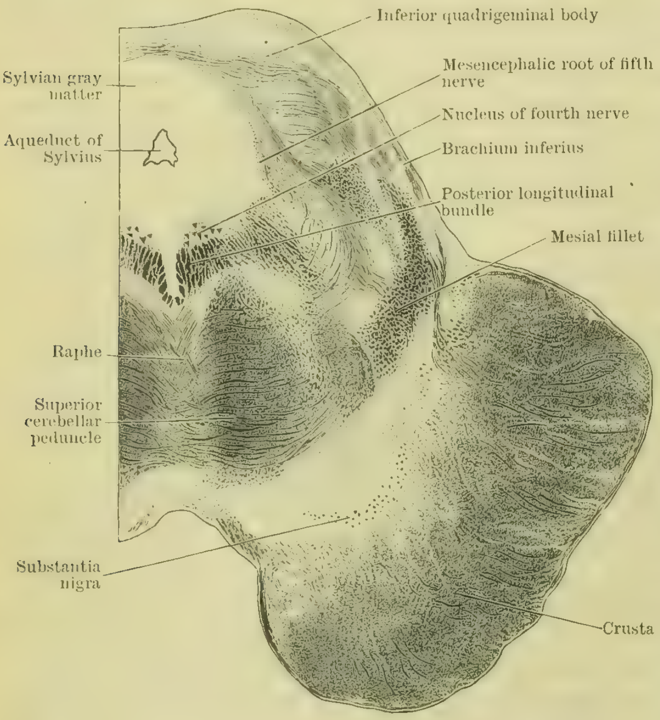


Fig. 365.—Transverse Section through the Human Mesencephalon at the Level of the Inferior Quadrigeminal Body.

The tegmentum of the crus cerebri may be considered as presenting two parts: viz. (1) a lower part, which is placed subjacent to the inferior quadrigeminal bodies and which is largely occupied by the decussation of the superior cerebellar peduncles (Fig. 365); and (2) a superior part, subjacent to the superior quadrigeminal bodies, which is traversed by the emerging bundles of the third nerve and which contains a large and striking nuclear mass, termed the nucleus ruber or the red tegmental nucleus (Fig. 366). In the lower part of the mesencephalon is the nucleus of the fourth nerve; in the upper part, the nucleus of the third nerve.

Superior Cerebellar Peduncles (brachia conjunctiva).—As the superior cerebellar peduncles leave the pons and sink into the tegmenta of the mesencephalon, they undergo a complete decussation subjacent to the inferior quadrigeminal bodies and the Sylvian gray matter (Figs. 347, p. 467; 367, p. 496; and 365). In this manner each peduncle is transferred from one side, across the mesial plane, to the opposite side. The decussation is completed at the level of the upper borders of the inferior quadrigeminal bodies, and then each peduncle proceeds upwards into the superior part of the tegmentum, where it encounters the red nucleus. Into this a large proportion of its fibres plunge and come to an end in connexion with the nuclear cells. Many of the peduncular fibres, however, are carried around the nucleus so as to form for it a capsule which is thicker on the inner than on the outer side (Fig. 366). These are prolonged into the subthalamic region, and ultimately reach the ventral aspect of the optic thalamus, into which they proceed. A certain number of these fibres end in connexion with the cells of the thalamus, whilst it is held by certain observers that the

remainder make their way through the optic thalamus, enter the posterior limb of the internal capsule, and, through this, are carried upwards to the cerebral cortex of the Rolandic area (Flechsig; Ferrier, and Turner). The superior cerebellar peduncle is, therefore, to be regarded as a great efferent tract which issues from the lateral hemisphere of the cerebellum, crosses the mesial plane in the lower part of the mesencephalon, and ends in the red nucleus, the ventral part of the optic thalamus and the Rolandic area of the cerebral cortex of the opposite side.

FIG. 366.—TRANSVERSE SECTION THROUGH THE HUMAN MESENCEPHALON AT THE LEVEL OF THE SUPERIOR QUADRIGEMINAL BODY.

Red Nucleus (nucleus ruber).—This is an elongated nuclear mass, of a reddish tint in the fresh brain, which lies in the upper part of the tegmentum, and in transverse section presents a circular outline. It begins at the level of the lower border of the superior quadrigeminal body and it extends upwards into the subthalamic tegmental region. At first it is small and is placed at a little distance from the mesial plane; but as it proceeds towards the subthalamic region, it increases in bulk and approaches more nearly to the mesial raphe, and its neighbour of the opposite side. The curved emerging bundles of the third nerve pass through it on their way to the surface. The relation which the fibres of the opposite superior cerebellar peduncle present to it has been described. These fibres traverse its lower part in such numbers that in Weigert-Pal specimens it presents a very dark colour; but higher up, as the fibres are gradually absorbed by the nuclear mass, they become less numerous in its midst, and the nucleus assumes a paler tint.

The **posterior longitudinal fasciculus** is a very conspicuous tract of longitudinal fibres which extends throughout the whole length of the medulla, pons, and mesencephalon, in the formatio reticularis or tegmental part of each. Below, at the level of the decussation of the pyramids, it becomes continuous with the anterior basis-bundle of the spinal cord (p. 455), whilst, by its opposite or upper end, it establishes intricate connexions in the region immediately above the mesencephalon. Throughout its whole length it lies close to the mesial plane and its fellow of the opposite side. In the mesencephalon it is applied to the ventral aspect of the Sylvian gray matter, whilst in the pons and medulla it is situated immediately subjacent to the gray matter of the floor of the fourth ventricle. One of its most

salient features is the intimate association which it presents with the three motor nuclei from which the nerves for the supply of the muscles of the eyeball take origin, viz. the oculo-motor or third nucleus, the trochlear or fourth nucleus, and the abducent or sixth nucleus. The first two of these are closely applied to its inner and dorsal aspect, whilst the abducent nucleus is placed on its outer side. Into each of these nuclei it sends many collaterals, and probably also some of its constituent fibres, and these end in terminal arborisations around the nuclear cells. It would appear, therefore, that one of the most important functions of this strand is to bind together these nuclei, and thus enable them to act in harmony with each other. Fibres also enter the posterior longitudinal fasciculus from the auditory system and perhaps, also, from the facial and other motor nuclei. The results obtained by degeneration would seem to indicate that, to a large extent, it is formed of fibres which run a short course within it.

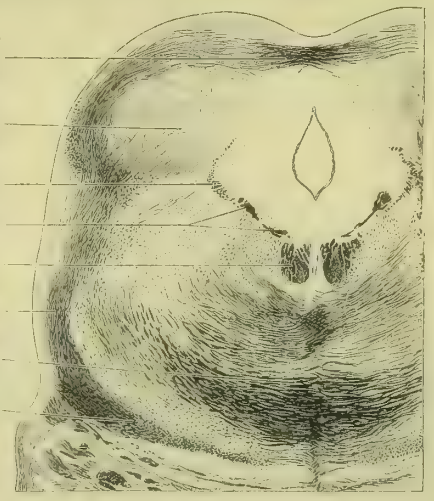


FIG. 367.—SECTION THROUGH THE INFERIOR QUADRIGEMINAL BODY AND THE TEGMENTUM OF THE MESENCEPHALON BELOW THE LEVEL OF THE NUCLEUS OF THE FOURTH NERVE IN THE ORANG. (The decussation of the superior cerebellar peduncles and the course of the fourth nerve in the Sylvian gray matter is seen.)

In spite of the large amount of attention which has been given to the study of the posterior longitudinal bundle, it must be admitted that there is little unanimity of opinion regarding its connexions and functions. That it is a brain tract of high importance is evident from the fact that it is present in all vertebrates, and, further, that its fibres assume their medullary sheaths at an extremely early period. In fish, amphibians, and reptiles, it is one of the most powerful bundles of the medulla. In man its fibres medullate between the sixth and seventh months of fœtal life, and at the same time as the fibres of the anterior basis-bundle of the cord, with which it stands in connexion.

According to Van Gehuchten and Edinger, it extends upwards beyond the level of the oculomotor nucleus, and in the subthalamic region its fibres take origin from a special nucleus of its own in the gray matter of the third ventricle, immediately below the level of the corpora mammillaria. Held asserts that numerous fibres, arising from cells in the superior quadrigeminal body, curve in an arcuate manner in the tegmentum outside the Sylvian gray matter, to take part on the ventral aspect of this in what is called the "fountain decussation." Reaching the opposite side these fibres turn downwards and join the posterior longitudinal fasciculus. The same authority considers that fibres from the ventral part of the posterior commissure can also be traced downwards into the posterior longitudinal bundle. Edinger, on the other hand, places these fibres as a distinct tract on the ventral and lateral aspect of the posterior longitudinal bundle, although in apposition with it.

FIG. 368.—SECTION THROUGH THE INFERIOR QUADRIGEMINAL BODY AND THE TEGMENTUM OF THE MESENCEPHALON, AT A SLIGHTLY LOWER LEVEL THAN FIG. 367.

Mendel believes that fibres from the oculo-motor nucleus are carried down in the posterior longitudinal bundle, and, from this, into the facial nerve for the supply of the orbicularis palpebrarum and the corrugator supercilii, bringing these muscles therefore under the control of the same nucleus as the levator palpebræ superioris muscle. This view has received corroboration at the hands of Tooth and Turner. It has been further suggested that fibres from the hypoglossal

nucleus may, by the posterior longitudinal fasciculus, reach the facial nerve, and through it the orbicularis oris. In this manner, therefore, the same nucleus would hold sway over the tongue and the sphincter muscle of the lips. The close relation which exists between the ascending part of the intrapontine portion of the facial nerve and the posterior longitudinal bundle would render the passage of fibres from one to the other a matter which could easily be understood. Another interchange of fibres through the posterior longitudinal bundle has been described by Duval and Laborde. According to these authorities, fibres from the abducent nucleus ascend in the posterior longitudinal bundle into the mesencephalon, and, crossing the mesial plane, pass out with the opposite oculo-motor nerve for the supply of the internal rectus muscle. If this view be correct, it affords a ready and simple anatomical explanation of the harmonious action of the external and internal recti muscles in producing movements of the two eyeballs simultaneously to the right and to the left.

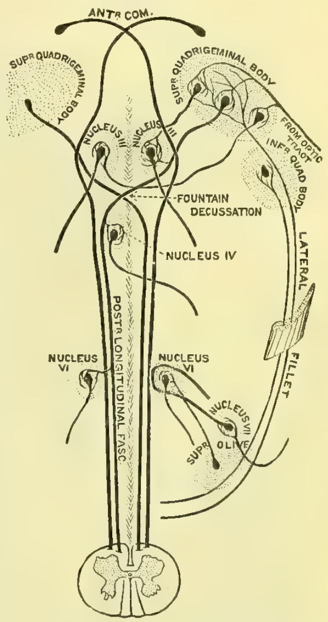


Fig. 369.—Diagram of the Connexions of the Posterior Longitudinal Bundle (after Held—modified).

Lateral Fillet (lemniscus lateralis).—The lateral fillet is a definite tract of longitudinal fibres, which extends upwards through the lateral part of the tegmental substance of the upper portion of the pons and the mesencephalon. It is formed by the fibres of the corpus trapezoides in the lower part of the pons, abruptly turning upwards and taking a course towards the quadrigeminal region. Entering into its constitution, therefore, are fibres from several sources, viz. (1) from the terminal cochlear nuclei of the opposite side; (2) from the terminal cochlear nuclei of the same side; (3) from the superior olivary nuclei. As the tract proceeds upwards a continuation of the gray matter of the superior olivary nucleus is carried up in connexion with it to form the nucleus of the lateral fillet, and from this fibres are also added to the strand. In the mesencephalon the fibres of the lateral fillet end in the nucleus of the inferior quadrigeminal body (p. 493) and in the gray substance of the corpus geniculatum internum, whilst a few are carried into the superior quadrigeminal body. The fibres which go to the inferior quadrigeminal body sweep outwards round the outer side of the superior cerebellar peduncle, and to some extent appear on the surface of the mesencephalon (p. 491).

But the lateral fillet cannot be considered as a tract composed entirely of ascending fibres belonging to the auditory system. It also contains descending fibres, the connexions and functions of which are not fully understood. These have been traced by Ferrier and Turner through the pons and medulla into the lateral column of the cord.

Mesial Fillet (lemniscus mesialis).—The mesial fillet has already been followed through the medulla and pons, and its position in each of these portions of the brain-stem has been defined (pp. 456 and 467). In the tegmentum of the lower part of the mesencephalon it is carried up in the form of a more or less flattened band on the ventral aspect of the decussating superior cerebellar peduncles. To its outer side, and forming an angle with it (as seen in transverse section), is the lateral fillet (Figs. 367 and 368), and at this level there is no clear demarcation between these two tracts. In the upper part of the mesencephalon the appearance of the red nucleus in the tegmentum causes the mesial fillet to take up a more lateral and dorsal position, so that it now comes to lie subjacent to the corpus geniculatum internum (Fig. 366, p. 495). At this level it exhibits a crescentic outline in transverse section, and the lateral fillet has to a large extent disappeared from its outer side.

The mesial fillet takes origin in the lower part of the medulla oblongata from the gracile and cuneate nuclei of the opposite side (p. 457). Seeing that the posterior column of the cord ends in these nuclei, the fillet may be considered to continue that column upwards into the brain. In the mesencephalon a considerable contribution of fibres is given by the mesial fillet to the superior quadrigeminal body, and then the remainder of the tract proceeds through the subthalamic tegmental region into the hinder part of the lateral nucleus of the optic thalamus.

Here many of its fibres end in terminal arborisations around the thalamic cells; whilst others, according to certain observers, emerge from the thalamus, enter the posterior limb of the internal capsule, and ascend through the corona radiata to the Rolandic area of the cerebral cortex, in which they, for the most part, end in the posterior central convolution (Flechsig).

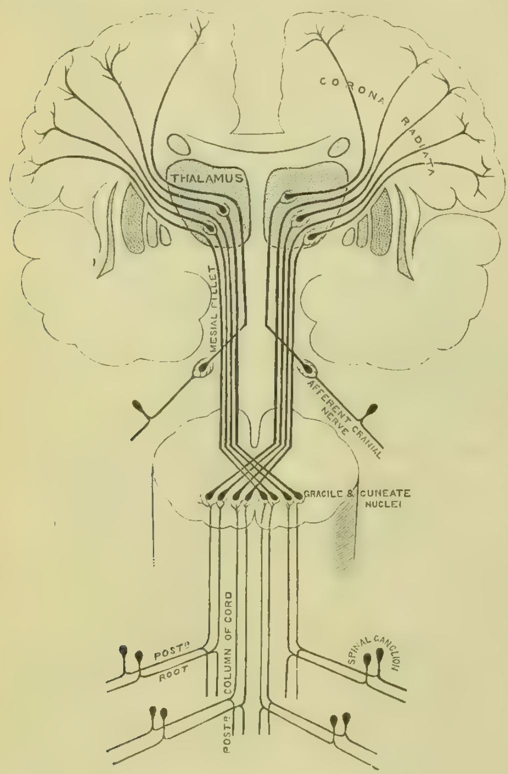


FIG. 370.—DIAGRAM OF THE CONNEXIONS OF THE MESIAL FILLET AND ALSO OF CERTAIN OF THE THALAMO-CORTICAL FIBRES.

Ganglion Interpedunculare and Fasciculus Retroflexus.—On the ventral aspect of the tegmentum close to the surface and to the mesial plane, there is a small group of cells in the lower part of the gray matter which forms the locus perforatus posticus. This is termed the *ganglion interpedunculare.* The *fasciculus retroflexus* is a small band of fibres which arises above in the ganglion habenulæ—a nuclear mass which will be studied in connexion with the diencephalon—and which runs downwards and forwards in the tegmentum of the upper part of the mesencephalon between the inner aspect of the nucleus ruber and the mesial plane, to end in the ganglion interpedunculare.

The Fountain Decussation.—If the region in front of the posterior longitudinal bundles be examined in the upper part of the mesencephalon a very close decussation of fibres in the mesial plane will be observed in the interval between the two red nuclei. This is the "fountain decussation." According to Held, the fibres which take part in the dorsal portion of the fountain decussation (decussation of Meynert) come from the superior quadrigeminal bodies, and, after they have gained the opposite side, they turn downwards in the posterior longitudinal fasciculus. The ventral part of the decussation (decussation of Forel) would appear to be formed by arcuate fibres of the tegmentum which arise in the gray matter of the Sylvian aqueduct.

Crusta or Pes of the Crus Cerebri (basis pedunculi).—The crusta presents a somewhat crescentic outline when seen in section, and it stands quite apart from its fellow of the opposite side. It is composed of a compact mass of longitudinally directed fibres, all of which, as Déjerine has shown, arise in the cortex of the cerebrum and pursue an unbroken corticifugal course into and through the crusta of the crus cerebri. These fibres may be classified into two distinct sets, viz. cortico-pontine and pyramidal.

The **cortico-pontine fibres** possess this leading peculiarity: in their course downwards they are all arrested in the ventral part of the pons Varolii and end in fine terminal arborisations around the cells of the nucleus pontis. They come from certain well-defined areas of cerebral cortex, viz. (1) the cortex of the prefrontal part of the frontal lobe, and (2) the cortex of the middle portion of the temporal lobe. These tracts would appear to hold a very definite position within the crus. Thus it has been satisfactorily established that the *temporo-pontine strand* forms the outer or lateral fifth of the crusta, whilst the recent researches of Ferrier and Turner render it more than likely that the *fronto-pontine strand* holds a similar position in the inner or mesial part of the crusta.

The **pyramidal fibres** constitute the great motor tract from the cerebral cortex. They occupy a position corresponding to the middle third of the crusta. The pyramidal tract differs from the cortico-pontine strands in being carried downwards through the ventral part of the pons and on the ventral aspect of the medulla into the cord, which it enters in the form of the crossed and direct pyramidal tracts. On its way through the pons and medulla it sends fibres to the various motor nuclei in those sections of the brain-stem.

Deep Origin of the Cranial Nerves which arise within the Mesencephalon.

Two of the motor cranial nerves, viz. the oculo-motor and the trochlear nerves, as well as the mesencephalic root of the trigeminal nerve, obtain origin within the mesencephalon. The nuclei from which they spring are all situated within the gray matter of the Sylvian aqueduct.

Mesencephalic Root of the Trigeminal Nerve (radix descendens).—The fibres of this root arise from a column of large, sparsely-arranged cells, which extends throughout the entire length of the mesencephalon. These cells lie in the outer part of the Sylvian gray matter, close to the tegmentum. The axons which emerge from the cells run downwards close to the outer surface of the Sylvian gray matter in the form of a small, gradually-increasing tract. In the lower part of the mesencephalon this tract assumes a crescentic outline, and ultimately comes to lie on the inner aspect of the superior cerebellar peduncle (Fig. 346, p. 466). The further course of the mesencephalic root of the fifth nerve through the upper part of the pons, to the point where it joins the emerging motor root of the trigeminal nerve, has already been traced (p. 485).

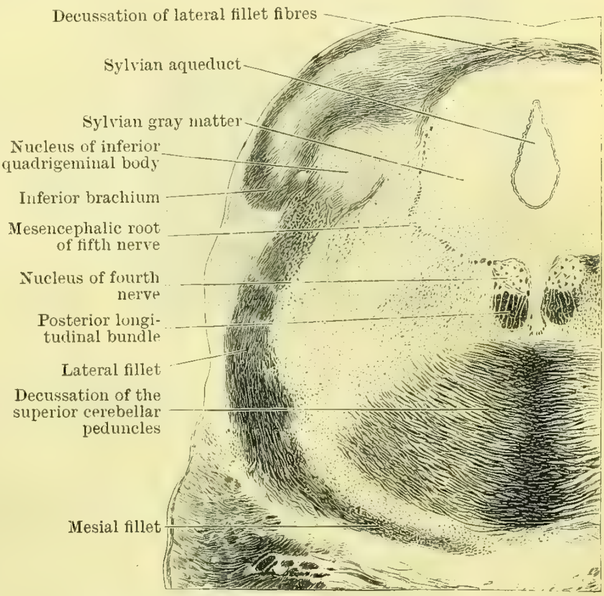


Fig. 371.—Section through the Inferior Quadrigeminal Body and the Tegmentum of the Mesencephalon at the Level of the Middle Part of the Nucleus of the Trochlear Nerve (Orang).

Trochlear or Fourth Nerve (nervus trochlearis).—The trochlear nerve supplies the superior oblique muscle of the eyeball. It emerges from the brain, on its dorsal aspect, at the upper part of the superior medullary velum, immediately below the lower border of the inferior quadrigeminal body (Fig. 373, p. 502). The nucleus from which it arises is a small oval mass of gray matter, placed in the ventral part of the Sylvian gray matter at the level of the upper part of the inferior quadrigeminal body. The close association of this nucleus with the posterior longitudinal bundle has already been alluded to. It is sunk deeply in a bay, which is hollowed out on the dorsal and inner aspect of that tract. The nerve has a course of some length within the mesencephalon. The axons of the cells leave the outer aspect of the nuclear mass, and curve backwards and outwards in the Sylvian gray matter until they reach the concave inner surface of the mesencephalic root of the trigeminal nerve. Here they are gathered together into one or two round bundles, which, bending sharply, turn downwards at a right angle and descend on the inner side of the trigeminal root. When the region below the inferior quadrigeminal body is reached, the nerve makes another sharp bend. This time it turns inwards, enters the upper end of the superior medullary velum, in which it decussates with its fellow of the opposite side. Having thus crossed the mesial plane, the trochlear nerve emerges at the inner border of the superior cerebellar peduncle. The course pursued by the fourth nerve within the Sylvian gray matter may be traced by examining in succession Fig. 372; Fig. 367, p. 496; Fig. 368, p. 496; and Fig. 347, p. 467.

Oculo-motor or Third Nerve (nervus oculo-motorius).—The oculo-motor nerve supplies the levator palpebræ superioris, all the ocular muscles, with the exception of the superior oblique and the external rectus, and also two muscles within the

eyeball, viz. the sphincter iridis and the musculus ciliaris. The nucleus of origin is placed in the ventral part of the Sylvian gray matter subjacent to the superior quadrigeminal body (Fig. 366, p. 495). In length it measures from 5 to 6 mm. Its lower end is partially continuous with the nucleus of the trochlear nerve, whilst its upper end extends upwards for a short distance beyond the mesencephalon into the gray matter on the lateral wall of the third ventricle. Its relation to the posterior longitudinal bundle is even more intimate than that of the trochlear nucleus. It is closely applied to the dorsal and inner aspect of this strand; many of its cells occupy a position in the intervals between the nerve bundles of the tract, and some even are seen on its ventral or tegmental aspect. The axons of the nuclear cells leave the nucleus in numerous bundles, which describe a series of curves as they proceed forwards through the posterior longitudinal bundle, the tegmentum, red nucleus, and inner margin of the substantia nigra, to finally emerge from the brain-stem along the bottom of the sulcus oculo-motorius on the inner aspect of the crus cerebri.

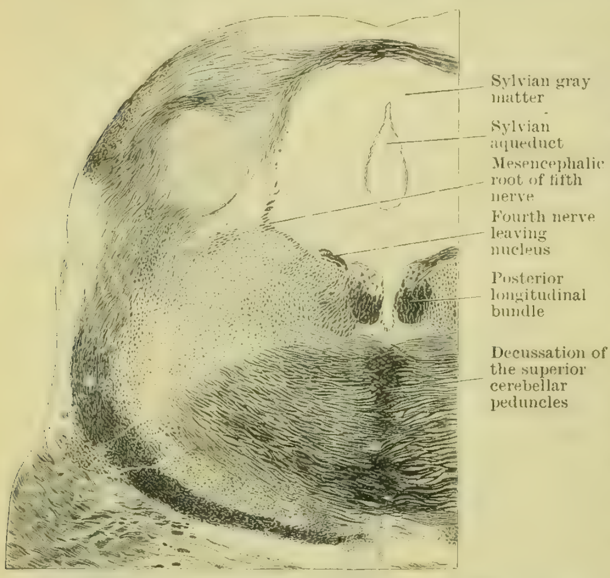


FIG. 372.—SECTION THROUGH THE INFERIOR QUADRIGEMINAL BODY AND THE TEGMENTUM OF THE MESENCEPHALON AT THE LEVEL OF THE LOWER PART OF THE NUCLEUS OF THE TROCHLEAR NERVE (ORANG).

The cells of the oculo-motor nucleus are not uniformly distributed throughout it. They are grouped into several more or less distinct collections or clumps, some of which possess cells which differ in size and appearance from the others. These cell-clusters are very generally believed to possess a definite relation to the several branches of the nerve and the muscles which they supply. Perlia recognises no less than seven such cell-clusters in each nucleus, with a small median nucleus placed accurately on the middle line, and from which fibres for both nerves spring. Whilst the majority of the fibres in the oculo-motor nerve arise from the cell-groups which lie on its own side of the mesial plane, it has been satisfactorily established that a certain proportion of its fibres are derived from the nucleus of the opposite side, thus forming a crossed connexion and giving rise to a median decussation. These crossed fibres are supposed by some to supply the internal rectus muscle; and if this be the case, the harmonious action of the external and internal recti muscles in producing the conjugate movements of the eyeballs could be understood without accepting in full the views of Duval and Laborde (p. 497).

The oculo-motor nucleus is connected—(1) with the occipital part of the cerebral cortex by fibres which reach it through the optic radiations; (2) with the trochlear and abducent nuclei (and probably with other nuclei) by fibres which come to it through the posterior longitudinal bundle; (3) possibly with the facial nerve by fibres which pass out from it into the posterior longitudinal bundle (p. 496); (4) with the visual system by fibres which enter it from the cells of the superior quadrigeminal body.

DEVELOPMENT OF THE MESENCEPHALON.

Even in the early embryo the mesencephalon constitutes the smallest section of the brain-tube, although the disproportion in size between it and the other primitive subdivisions of the brain is not nearly so marked as in the adult. Owing to the cephalic flexure, the mid-brain for a time occupies the highest part of the summit of the head. Later on it becomes completely covered over by the expanding cerebral hemispheres.

The corpora quadrigemina are derived from the alar laminæ of the lateral walls of the brain-tube, whilst the basal laminæ thicken and ultimately form the tegmenta and crustæ of the two crura cerebri. The original cavity of the mid-brain is retained as the aqueduct of Sylvius.

For a considerable time the cavity of the mesencephalon remains relatively large, and the lower part of its dorsal wall is carried downwards in the form of a diverticulum or recess, which overlaps the cerebellar plate. About this time, also, the dorsal wall shows a

median fold or ridge. Both of these conditions are transitory. As the corpora quadrigemina take shape, the median ridge disappears and is replaced by the median longitudinal groove, which separates the quadrigeminal bodies. Only its lower part is retained, and this is represented by the frenulum veli of the adult brain. The diverticulum of the cavity gradually becomes reduced, and finally disappears as the aqueduct assumes form.

FORE-BRAIN.

Parts derived from the Diencephalon.

Under this heading we have to consider: (1) the **thalamus**; (2) the **epithalamus**, which comprises the pineal body and the habenular region; (3) the **metathalamus**, or the corpora geniculata; and (4) the **hypothalamus**.

The hypothalamus consists of two portions, viz. the **pars mammillaris hypothalami**, which comprises the corpus mammillare and the portion of the central gray matter which forms the floor of the third ventricle in its immediate vicinity; and the **pars optica hypothalami**, which embraces the tuber cinereum, the infundibulum, the pituitary body, and the lamina cinerea. Strictly speaking, the optic part of the hypothalamus does not belong to the diencephalon, but it is convenient to study the parts which it represents at this stage. It is also convenient to examine, at the same time, the **subthalamic tegmental region**, although a very considerable part of this is apparently developed in connexion with the mesencephalon.

The original cavity of that part of the brain-tube which forms the diencephalon is represented by the greater part of the third ventricle of the brain.

Optic Thalamus (thalamus).—The optic thalamus is the principal object in this section of the brain. It is a large ovoid mass of gray matter, which lies obliquely across the path of the crus cerebri as it ascends into the cerebrum. The smaller anterior end of the thalamus lies close to the mesial plane, and is only separated from the corresponding part of the opposite side by a very narrow interval. The enlarged posterior ends of the two thalami are placed more widely apart, and in the interval between them the corpora quadrigemina are situated. As previously stated, the crusta of the crus cerebri, composed of corticifugal fibres, gradually inclines outwards as it is traced upwards, and thus it assumes a place on the outer aspect of the optic thalamus and passes into the internal capsule of the brain. The tegmental part of the crus, on the other hand, comes into relation with the under surface of the thalamus, and forms in this situation the **subthalamic tegmental region**. To a very large extent the longitudinal fibres of the tegmentum are corticipetal. For the most part they enter the thalamus, and either end within it in fine arborisations around the thalamic cells or are carried upwards through the thalamus into the internal capsule.

The two optic thalami, in their anterior two-thirds, lie close together on either side of a deep mesial cleft, which receives the name of the third ventricle of the brain. Each thalamus presents an anterior and a posterior extremity and four surfaces. The inferior and external surfaces are in apposition, and, indeed, directly connected with adjacent parts of the brain, and on this account it is only possible to study them by means of sections through the brain. The superior and internal surfaces are free.

The *external* or *lateral surface* of the thalamus is applied to a thick layer of white matter interposed between it and the lenticular nucleus, called the **internal capsule**, and composed of fibres passing both upwards towards, and downwards from, the cerebral cortex. A large proportion of these fibres descend to form the crusta or ventral part of the crus cerebri. From the entire extent of the external surface of the thalamus large numbers of fibres stream out and enter the internal capsule, to reach the cerebral cortex. These fibres constitute what is termed the **thalamic radiation**, and by this the thalamus is brought into connexion with the entire extent of the cerebral cortex. As the fibres leave the thalamus they intersect each other at acute angles, and over the whole of the external surface of the ganglionic mass they form a very distinct reticulated zone or stratum, which is termed the **external medullary lamina**.

The *inferior* or *ventral surface* of the thalamus rests chiefly on the subthalamic

tegmental region and the corpus mammillare. In front, however, as the tegmental substance gradually disappears, the thalamus comes to lie over the outer part of the tuber cinereum. From the subthalamic region many fibres enter the thalamus on its under aspect, whilst other fibres leave this surface of the thalamus to take part in the thalamic radiation.

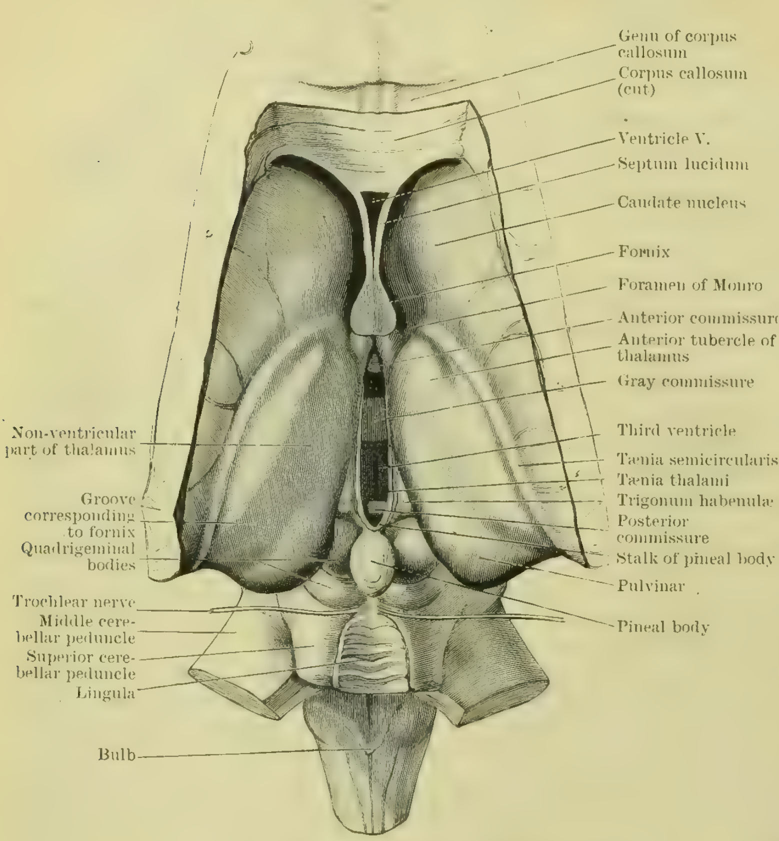


FIG. 373.—THE TWO OPTIC THALAMI (as seen from above).

The *superior* or *dorsal surface* of the thalamus is free. Externally it is bounded by a groove, which traverses the floor of the lateral ventricle of the brain and intervenes between the thalamus and the caudate nucleus. In this groove are placed a slender band of longitudinal fibres, termed the tænia semicularis, and in its fore-part the vein of the corpus striatum. Internally, the superior surface of the thalamus is separated from the internal or mesial surface in its anterior half by a sharp edge or prominent ledge of the ependyma of the third ventricle. This is termed the **tænia thalami**, and the ridge which it forms is accentuated by the fact that, subjacent to it, there lies a longitudinal strand of fibres called the **stria medullaris**. When these two structures, viz. the ependymal ridge and the subjacent tract, are traced backwards, they are seen to turn inwards and become continuous with the stalk or peduncle of the pineal body. Behind the portion of the tænia thalami which turns inwards towards the pineal body a small depressed triangular area, the **trigonum habenulæ**, situated in front of the superior quadrigeminal body, forms a very definite inner boundary for the hinder part of the superior surface of the thalamus.

The superior surface of the thalamus is slightly bulging or convex, and is of a whitish colour, owing to the presence of a thin superficial covering of nerve-fibres, termed the **stratum zonale**. It is divided into two areas by a faint oblique groove, which begins in front at the inner border, a short distance behind the anterior extremity of the thalamus, and extends outwards and backwards to the outer part of the hinder end. This groove corresponds to the outer edge of the fornix. The two areas which are thus mapped out are very differently related to the ventricles of the brain, and also to the parts which lie above the thalamus. The *outer area*, which includes the anterior extremity of the thalamus, forms a part of the floor of the lateral ventricle. It is covered with ependyma, overlapped by .the choroid plexus of this ventricle, and lies immediately subjacent to the corpus callosum. Along the line of the groove the epithelial lining of the lateral ventricle is reflected

over the choroid plexus of this cavity. The *inner area*, which includes the hinder end of the thalamus, intervenes between the lateral and third ventricles of the brain, and takes no part in the formation of the walls of either. It is covered by a fold of pia mater, termed the velum interpositum, above which is the fornix, and these two structures intervene between the thalamus and the corpus callosum.

The *anterior extremity* of the thalamus, called the **anterior tubercle** (tuberculum anterius thalami), forms a marked bulging. It projects into the lateral ventricle, behind and to the outer side of the free portion of the anterior pillar of the fornix. The foramen of Monro, a narrow aperture of communication between the lateral and third ventricles of the brain, is bounded in front by the anterior pillar of the fornix and behind by the anterior tubercle of the thalamus.

The *posterior extremity* of the thalamus is very prominent and forms a cushion-like projection, which overhangs the brachia of the corpora quadrigemina. This prominence is called the **pulvinar.** Another oval bulging on the hinder part of the thalamus receives the name of the **corpus geniculatum externum.** It is situated below, and to the outer side of, the pulvinar, and presents a very intimate connexion with the optic tract.

The *mesial surfaces* of the two thalami are placed very close together, and are covered not only by the lining ependyma of the third ventricle, but also by a tolerably thick layer of gray matter, continuous below with the central gray substance which surrounds the aqueduct of Sylvius in the mesencephalon. A band of gray matter, termed the **gray or soft commissure** (commissura mollis), crosses the third ventricle and joins the inner surfaces of the two thalami together.

Intimate Structure and Connexions of the Optic Thalamus.—The upper surface of the thalamus is covered by the **stratum zonale,** a thin coating of white fibres derived to some extent from the optic tract, and probably also from the optic radiation. The inner surface has a thick coating of central gray matter, whilst intervening between the internal capsule and the outer surface is the **lamina medullaris externa.** The lower surface merges into the subthalamic region.

The gray matter of the optic thalamus is marked off into three very apparent parts—termed the anterior, the mesial, and the lateral thalamic nuclei—by a thin vertical sheet of white matter, termed the **lamina medullaris interna.** The **lateral nucleus** (nucleus lateralis thalami) is by far the largest of the three. It is placed between the internal and the external medullary laminæ, and it stretches backwards beyond the mesial nucleus, and thus includes the whole of the pulvinar (Fig. 375). The **mesial nucleus** (nucleus medialis thalami) only reaches as far back as the habenular region. It is placed between the central gray matter of the third ventricle and the internal medullary lamina. The lateral nucleus is more extensively pervaded by fibres than the mesial nucleus. From the lateral nucleus by far the greatest number of the fibres which form the **radiatio thalami** pass, and these are seen crossing it in various directions towards the lamina medullaris externa. The **anterior nucleus** (nucleus anterior thalami) is the smallest of the three thalamic nuclei. It forms the prominent anterior tubercle, and is prolonged in a wedge-shaped manner, for a short distance, downwards and backwards between the anterior parts of the mesial and lateral nuclei. The internal medullary lamina splits into two parts and partially encloses the anterior nucleus. In connexion with its large cells a very conspicuous bundle of fibres, the **bundle of Vicq d'Azyr** (fasciculus thalamo-mammillaris), which arises in the corpus mammillare, comes to an end.

Two other small nuclear masses are found in the substance of the optic thalamus behind the mesial nucleus. These are called the **central nucleus of Luys** and the **nucleus arcuatus.** In section the former appears as a circular mass of gray matter, which comes into view immediately behind the point where the internal medullary lamina disappears. It would seem to be intimately connected with fibres which reach it from the red nucleus and from the posterior commissure. These fibres pass round it so as to mark it off from the rest of the thalamus, and in front of the nucleus many of them enter the internal medullary lamina. The **nucleus arcuatus** is a small semilunar mass of gray matter placed below the central nucleus of Luys.

The **connexions of the thalamus** are of an extremely intricate kind. It would appear to be a ganglionic mass interposed between the tegmental corticipetal tracts and the cerebral cortex. In its hinder part, and through its stratum zonale, it also

has important connexions with the optic tract. The corticipetal tegmental tracts, which enter it from below, will be noticed in connexion with the subthalamic region. Suffice it to say, for the present, that many of these fibres end in the midst of the thalamus in connexion with the thalamic cells, whilst others are apparently carried directly upwards through it to enter the internal capsule; the latter without any break in their continuity, reach the cortex of the cerebrum. In addition to these, enormous numbers of fibres, arising within the thalamus as the axons of its cells, stream out from its outer and under surfaces to form the thalamic radiation. These fibres pass to every part of the cortex; and although there is no separation of them into distinct groups as they leave the thalamus, it is customary to regard them as constituting a frontal stalk, a parietal stalk, an occipital stalk, and a ventral stalk.

The **frontal stalk** of the thalamic radiation emerges from the anterior part of the lateral surface of the thalamus and passes through the anterior limb of the internal capsule, to reach the cortex of the frontal lobe. Many of these fibres end in the caudate and lenticular nuclei, between which they proceed. The **parietal stalk** issues from the lateral surface of the thalamus, and, passing through the internal capsule (and to some extent, also, through the lenticular nucleus and the external capsule), gains the cortex of the hinder part of the frontal lobe and of the parietal lobe. The **occipital stalk** emerges from the outer aspect of the pulvinar and constitutes the so-called optic radiation. These fibres sweep outwards and backwards round the outer side of the posterior horn of the lateral ventricle to gain the cortex of the occipital lobe. The **ventral stalk** streams out from the under aspect of the anterior part of the thalamus, in front of the subthalamic tegmental region and the corpus mammillare. Its fibres arise in both the mesial and lateral nuclei, and sweep downwards and outwards to reach the region below the lenticular nucleus. One very distinct band which lies dorsal to the other fibres (ansa lenticularis) enters the lenticular nucleus, whilst the remainder (ansa peduncularis) continue in an outward direction below the lenticular nucleus and gain the cortex of the temporal lobe and of the insula or island of Reil.

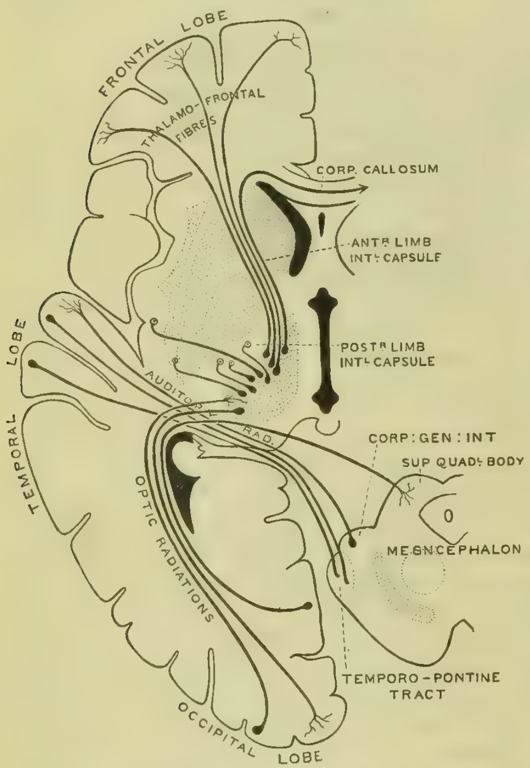


FIG. 374.—SCHEMA. Founded on the observations of Flechsig, and Ferrier and Turner.

Flechsig divides the thalamo-cortical fibres of ordinary sensation into three sensory systems. These he has been able to distinguish by studying the order in which they assume their sheaths of myelin in the fœtus and infant.

Ferrier and Turner, by the degenerative method of investigation, corroborate Flechsig's results in a very remarkable manner. They confirm the observation of Flechsig that, while thalamic fibres are distributed to the several regions of the cerebral cortex to an almost equal extent, there is one district, viz. the frontal pole, to which the supply is scanty. Another very important result has been obtained by these authors. They have established the fact that many of the thalamic fibres cross the mesial plane in the corpus callosum, and thus gain the cortex of the opposite cerebral hemisphere. Hamilton's crossed callosal tract thus receives confirmation.

Intimate Structure of the Corpus Geniculatum Externum.—Sections through the external geniculate body reveal the fact that it is composed of a series of alternately placed gray and white curved laminæ. This gives it a very characteristic appearance. The white laminæ are composed of fibres which enter the body from the optic tract and the optic radiation. The connexions of the geniculate bodies will be studied with the optic tract.

Subthalamic Tegmental Region.—The tegmental part of the crus cerebri is prolonged upwards and assumes a position below the hinder part of the thalamus.

The **red nucleus** is a conspicuous object in sections through the lower part of this region. It presents the same appearance as lower down in the mesencephalon, and, gradually diminishing, it disappears before the level of the corpus mammillare is reached. Carried up around it are the same longitudinal tracts of fibres which have been studied in relation to it in the tegmental part of the mesencephalon. The fibres of the **superior cerebellar peduncle**, as they proceed upwards, form a coating for it, which is distinctly thicker on its inner than on its outer surface. The **mesial fillet**, also, which in the upper part of the mesencephalon is observed to take up a position on the lateral and dorsal aspect of the red nucleus, maintains a similar position in the subthalamic region. When the red nucleus comes to an end these various fibres are continued onwards and form, in the position previously occupied by the nucleus, a very evident and dense mass of fibres. The fibres of the mesial fillet and of the superior cerebellar peduncle are prolonged upwards into the ventral part of the thalamus, where a certain number of them end in connexion with the thalamic cells. The remainder apparently proceed directly through the ganglionic mass into the internal capsule, and thus gain the hinder part of the Rolandic area of the cerebral cortex.

The **substantia nigra** is likewise carried into the subthalamic region, where it maintains its original position on the dorsal aspect of the crusta of the crus cerebri. As it is traced upwards, it is seen to gradually diminish in amount. It shrinks from within outwards, and finally disappears when the hinder part of the corpus mammillare is reached.

In coronal sections through the subthalamic region, the most conspicuous object which comes into view is the **corpus subthalamicum** or the **nucleus of Luys**. It is a small mass of gray matter, shaped like a biconvex lens, which makes its appearance on the dorsal aspect of the crusta of the crus cerebri immediately to the outer side of the substantia nigra. At first it lies in an angle, which is formed by the meeting of the crusta and the internal capsule; but, rapidly enlarging in an inward direction, it takes the place of the diminishing substantia nigra on the dorsal surface of the crusta at the level of the lower part of the corpus mammillare. The corpus subthalamicum is rendered all the more evident by the fact that it is sharply defined by a thin capsule of white fibres. On its mesial aspect these fibres proceed inwards and form a very evident decussation across the middle line in the floor of the third ventricle, immediately above the hinder ends of the corpora mammillaria.

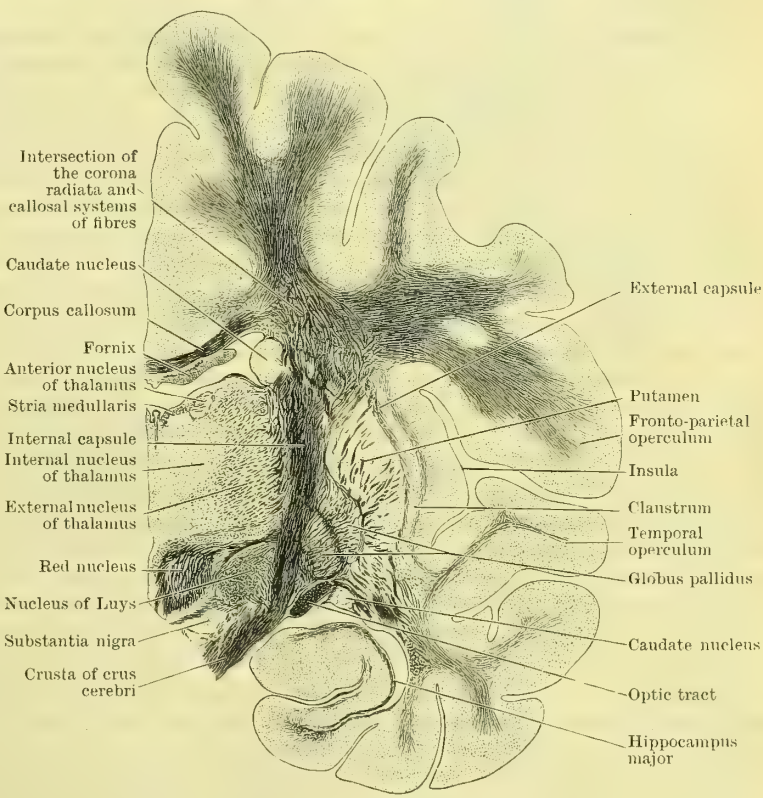


FIG. 375.—CORONAL SECTION THROUGH THE CEREBRUM OF AN ORANG PASSING THROUGH THE SUBTHALAMIC TEGMENTAL REGION.

The corpus subthalamicum, in the fresh condition, presents a brownish colour, partly from the fact that its cells are pigmented, and partly also on account of the numerous capillary blood-vessels which pervade its substance.

Pineal Body (corpus pineale).—This is a small, dark, reddish body, about the size of a cherry-stone and shaped after the fashion of a fir-cone. Placed between the hinder ends of the two thalami, it occupies the depression on the dorsal aspect of the mesencephalon, which intervenes between the two superior quadrigeminal bodies. Its base, which is directed upwards, is attached by a hollow stalk or peduncle. This stalk is separated into a dorsal and a ventral part by the prolongation backwards into it of a small pointed recess of the cavity of the third ventricle. The dorsal part of the stalk curves outwards and forwards, and on each optic thalamus becomes continuous with the tænia thalami and the subjacent stria medullaris; the ventral part is folded round a narrow but conspicuous, cord-like band of white matter, which crosses the mesial plane immediately above the base of the pineal body and receives the name of the **posterior commissure** of the cerebrum.

The pineal body is not composed of nervous elements. The only nerves in its midst are the sympathetic filaments which enter it, with its blood-vessels. It is composed of spherical and tubular follicles, filled with epithelial cells, and containing a variable amount of gritty, calcareous matter.

The pineal body is a rudimentary structure, but in certain vertebrates it attains a much higher degree of development than in man. In the lizard, blind-worm, etc., it is present in the form of the so-called pineal eye. In structure it resembles, in these animals, an invertebrate eye, and it possesses a long stalk, in which nerve-fibres are developed. Further, it is carried through an aperture in the cranial wall, and consequently lies close to the surface.

Trigonum Habenulæ.—The small, triangular, depressed area which receives this name is placed immediately in front of the superior quadrigeminal body in the interval between the peduncle of the pineal body and the hinder end of the thalamus (Fig. 373, p. 502). It marks the position of an important collection of nerve-cells, which constitute the **ganglion habenulæ**. The axons of these cells are collected on the ventral aspect of the ganglion into a bundle, called the **fasciculus retroflexus**, which takes a curved course downwards and forwards in the tegmentum of the mesencephalon. The fasciculus retroflexus lies close to the inner side of the red nucleus, and finally comes to an end in a group of cells termed the **ganglion interpedunculare**, situated in the lower part of the locus perforatus posticus (see p. 498).

The ganglion habenulæ is likewise intimately connected with the stria medullaris and the dorsal part of the stalk of the pineal body.

As previously stated, the **stria medullaris**—a very evident band of white matter—lies on the optic thalamus, subjacent to the ependymal ridge termed the tænia thalami. When traced backwards, many of the fibres of the stria medullaris are observed to end amongst the cells of the ganglion habenulæ, whilst others are continued past the ganglion to enter the peduncle of the pineal body, and, through it, to reach the ganglion habenulæ of the opposite side, in connexion with the cells of which they terminate. The stria medullaris, therefore, ends partly in the ganglion habenulæ of its own side and partly in the corresponding ganglion of the opposite side. The decussation of fibres across the middle line forms the dorsal part of the pineal stalk or peduncle, and is frequently termed the **commissura habenularum.**

When the stria medullaris is traced in the opposite direction, it is noticed to split into a dorsal and ventral part near the anterior pillar of the fornix. The *dorsal part* turns abruptly upwards, and, joining the fornix, is carried in it to the hippocampus major or cornu ammonis from cells in which its fibres take origin. The *ventral part* turns downwards and appears to spring from a collection of cells in the gray matter on the base of the brain close to the optic chiasma. The stria medullaris is believed to form a part of the olfactory apparatus.

Commissura Posterior.—The posterior commissure is a slender band of white matter, which crosses the middle line under cover of the stalk of the pineal body and overlies the entrance of the aqueduct of Sylvius into the third ventricle. The connexions of this little band are not satisfactorily established, but Held believes

that some of its ventral fibres pass downwards into the posterior longitudinal bundle. Ferrier and Turner have traced fibres from the optic radiation across the middle line in the posterior commissure.

The **locus perforatus posticus** (substantia perforata posterior) has already been described on p. 440. Some delicate bands of white matter, termed the **tænia pontis**, may frequently be seen emerging from the gray matter of this region; they then curve round the crura cerebri in close relation to the upper border of the pons, into which they ultimately sink (Fig. 335, p. 449).

Corpora Mammillaria.—The corpora mammillaria are two round white bodies, each about the size of a pea, which lie side by side in the interpeduncular space on the base of the brain, immediately in front of the locus perforatus posticus.

Each corpus mammillare is coated on the outside by white matter derived from the anterior pillar of the fornix and contains, in its interior, a gray nucleus with numerous nerve-cells. Several important strands of fibres are connected with the corpus mammillare: (1) The **anterior pillar of the fornix** curves downwards in the lateral wall of the third ventricle to reach the corpus mammillare, and its fibres end amidst the cells of that body. (2) A bundle of fibres, called the **bundle of Vicq d'Azyr**, which at first sight appears to be almost continuous with the anterior pillar of the fornix, takes origin in its midst and extends upwards into the optic thalamus, to end in fine arborisations around the large cells in the anterior thalamic nucleus. (3) Another bundle of fibres, the **pedunculus corporis mammillaris**, takes form within the corpus mammillare and extends downwards in the gray matter of the floor of the third ventricle, to reach the tegmentum of the mesencephalon. The ultimate destination of these fibres is doubtful.

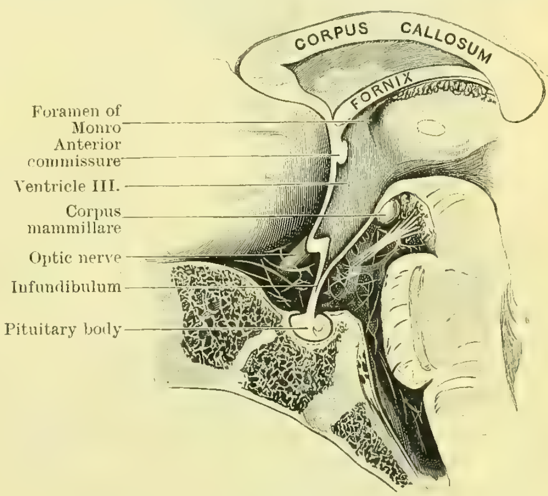


Fig. 376.—Mesial Section through the Pituitary Region in a Child of Twelve Months old.
From a photograph by Professor Symington.

Tuber Cinereum and Infundibulum.—The tuber cinereum is a small, slightly prominent field of gray matter, which occupies the anterior part of the interpeduncular space between the corpora mammillaria behind and the optic chiasma in front. From its fore-part the **infundibulum**, or stalk of the pituitary body, projects downwards and connects that body with the base of the brain. In its upper part the infundibulum is hollow, a small, funnel-shaped diverticulum of the cavity of the third ventricle being prolonged downwards into it.

Pituitary Body (hypophysis).—This is a small oval structure, flattened from above downwards, and with its long axis directed transversely, which occupies the pituitary fossa in the floor of the cranium. It is composed of two lobes—a large anterior lobe and a smaller posterior lobe, which are closely applied the one to the other. The infundibulum, which extends downwards from the tuber cinereum, is attached to the posterior lobe.

The infundibulum and posterior lobe of the pituitary body are developed in the form of a hollow diverticulum, which grows downwards from the floor of that part of the embryonic brain, which afterwards forms the third ventricle. The original cavity of this diverticulum becomes obliterated, except in the upper part of the infundibulum. In structure, the posterior lobe of the pituitary body shows little trace of its origin from the wall of the brain-tube. It is chiefly composed of connective tissue and blood-vessels, with branched cells scattered throughout it.

The anterior lobe has quite a different origin, and if any part of the pituitary body is functional, it is this lobe. It is derived by a tubular diverticulum, which grows upwards

from the buccal cavity. Its connexion with the latter is soon cut off, and it becomes encased within the cranial cavity in intimate association with the cerebral portion of the organ. Structurally, it consists of tubules or alveoli, lined by epithelial cells and surrounded by capillary vessels. Its structure is not unlike that of the thyroid body, and possibly it exercises a similar function. In giants, and in cases of acromegaly, the pituitary body is usually greatly enlarged.

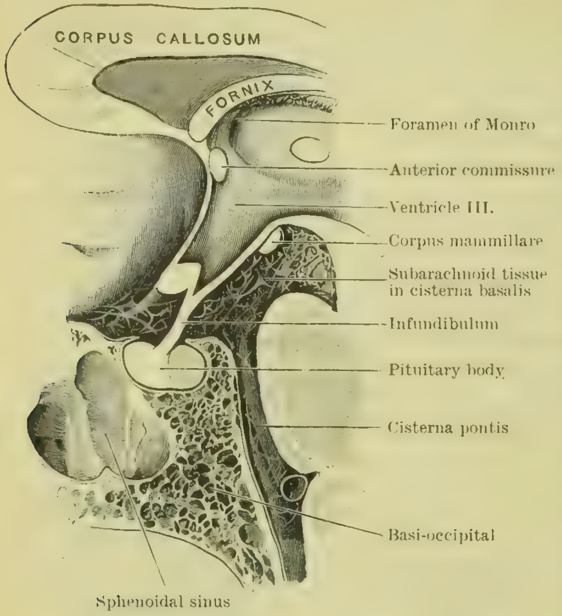


FIG. 377.—MESIAL SECTION THROUGH THE PITUITARY REGION IN THE ADULT.

Lamina Cinerea.—This is a thin lamina which passes upwards from the optic chiasma in the great longitudinal fissure to become connected with the rostrum of the corpus callosum.

Anterior Commissure of the Cerebrum.—In the anterior part of the cleft, between the two optic thalami and immediately in front of the anterior pillars of the fornix, a round bundle of fibres crosses the mesial plane. This is the anterior commissure. It is much larger than the posterior commissure.

Third Ventricle (ventriculus tertius).—This is the narrow cleft which separates the two optic thalami. Its depth rapidly increases from behind forwards, and it may be said to extend from the pineal body behind to the lamina cinerea in front. Its *floor* is formed by the structures already studied within the area of the interpeduncular space on the base of the brain, viz. the tuber cinereum, the corpora mammillaria, the gray matter of the locus perforatus posticus, and also to some extent behind this by the tegmenta of the crura cerebri. It is interesting to note that the central gray matter which surrounds the Sylvian aqueduct is directly continuous with the gray matter of the locus perforatus posticus and tuber cinereum, and in this way it comes to the surface in the base of the brain. The optic chiasma crosses the floor in front and marks the place where the latter becomes continuous with the anterior wall of the cavity. The *front wall* of the third ventricle is formed by the lamina cinerea, which extends upwards from the optic chiasma. The anterior commissure, as it crosses from one side to the other, projects into the ventricle, but of course it is excluded from the cavity by the ventricular epithelial lining. It may be taken as indicating the place where the roof joins the anterior wall. The *roof* of the third ventricle is formed by a thin epithelial layer, continuous with the thin epithelial lining of the cavity, which stretches across the mesial plane from one tænia thalami to the other. Applied to the upper surface of the epithelial roof is the fold of pia mater, termed the velum interpositum, and the roof is invaginated into the cavity along its whole length by two delicate choroid plexuses, which hang down from the under surface of this fold. When the velum interpositum is removed the thin epithelial roof is torn away with it, leaving only the lines of attachment in the shape of the tænia thalami.

The *lateral wall* of the third ventricle is formed for the greater part of its extent by the inner surface of the optic thalamus, covered by a thick layer of central gray matter continuous with the Sylvian gray matter of the mesencephalon. A little in front of the middle of the ventricle the cavity is crossed by the **middle or soft commissure**, which connects the thalami with each other, and in front of this the anterior pillar of the fornix is seen curving downwards and backwards in the lateral wall. At first the bulging which it forms is distinctly prominent, but it

gradually subsides as the strand, on its way to end in the corpus mammillare, becomes more and more sunk in the gray matter on the side of the ventricle.

The third ventricle communicates with both of the lateral ventricles, and also

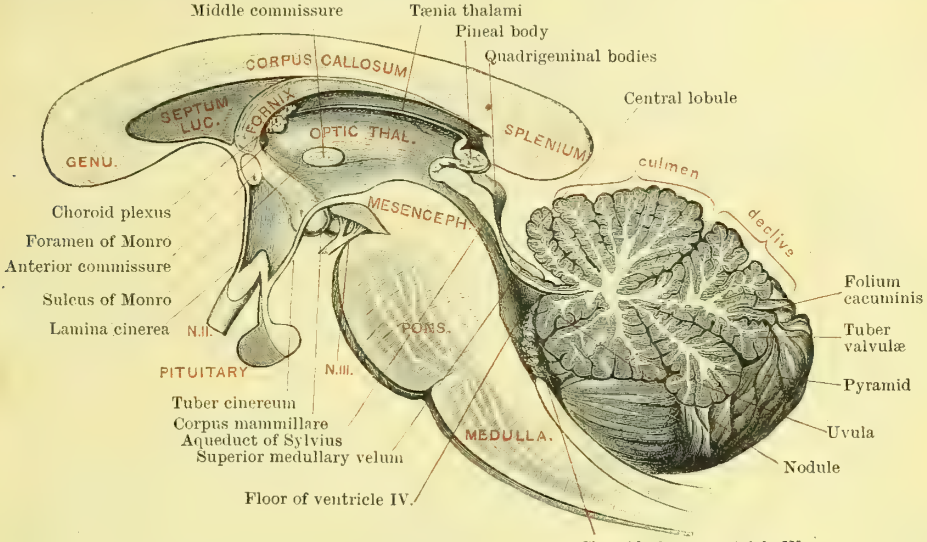


FIG. 378.—MESIAL SECTION THROUGH THE CORPUS CALLOSUM, DIENCEPHALON, ETC. Shows the third and fourth ventricles connected by the aqueduct of Sylvius.

with the fourth ventricle. The **aqueduct of Sylvius**, the narrow channel which tunnels the mesencephalon, brings it into communication with the fourth ventricle. The opening of this aqueduct is placed at the posterior part of the floor of the third ventricle, immediately below the posterior commissure. The **foramina of Monro**

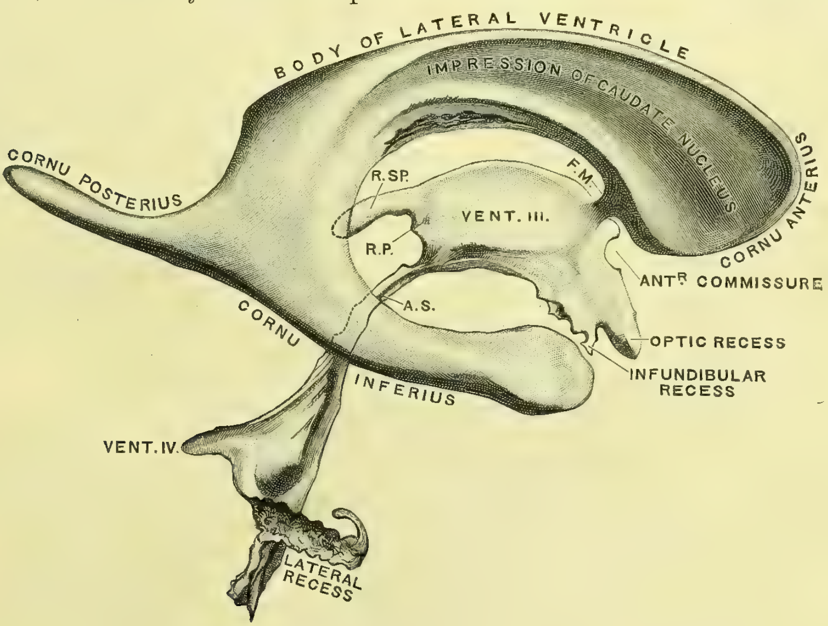


FIG. 379.—CAST OF THE VENTRICLES OF THE BRAIN (from Retzius).

R.SP. Recessus suprapinealis.
R.P. Recessus pinealis inferius.
A.S. Aqueduct of Sylvius.
F.M. Foramen of Monro.

bring it into communication with the lateral ventricles. These apertures are placed at the upper and fore parts of the lateral walls, and lead outwards and slightly upwards between the most prominent parts of the anterior pillars of the fornix and the anterior tubercles of the optic thalami. They are just large enough

to admit a crow-quill, and through these passages the epithelial lining of the three ventricles becomes continuous. From the foramen of Monro a distinct groove on the lateral wall of the ventricle leads backwards towards the mouth of the Sylvian aqueduct. It is termed the **sulcus of Monro**, and is of importance, inasmuch as it represents in the adult brain the furrow which divides the lateral wall of the embryonic brain-tube into an alar and a basal lamina.

The outline of the third ventricle, when viewed from the side in a mesial section through the brain, or as it is exhibited in a plaster cast of the ventricular system of the brain, is seen to be very irregular. It presents several diverticula or recesses. Thus, in the fore-part of the floor there is a deep, funnel-shaped pit or recess, leading down through the tuber cinereum into the infundibulum of the pituitary body. Another recess, the *recessus opticus*, leads forwards immediately in front of this, above the optic chiasma. Posteriorly two diverticula are present. One, the *recessus pinealis*, passes backwards above the posterior commissure and the mouth of the Sylvian aqueduct for a short distance into the stalk of the pineal body. The second is placed above this and is carried backwards for a greater distance. It is a diverticulum of the epithelial roof, and, therefore, is difficult to demonstrate. It is termed the *recessus suprapinealis*.

Cerebral Connexions of the Optic Tract.

One nerve, the optic nerve or the nerve of sight, is connected with this section of the brain. At the optic chiasma the optic nerves of the two sides are joined together and a partial decussation of fibres takes place. The fibres which arise in the mesial half of each retina cross the mesial plane and join the optic tract of the opposite side. The optic tract proceeds backwards round the crus cerebri, and in the neighbourhood of the corpora geniculata divides into two roots, viz. a lateral and a mesial (p. 491).

Mesial Root of the Optic Tract—The Commissure of Gudden.—The mesial root of the optic tract disappears under cover of the corpus geniculatum internum and a large proportion of its fibres arise in this nuclear body. As to the origin of the other fibres, we possess at present no precise information. The mesial root, although it is composed of fibres which run in the optic tract, has absolutely nothing to do with the optic nerve. These fibres, when traced forwards, cross the mesial plane in the posterior angle of the optic chiasma and are carried backwards in the opposite optic tract, to form on that side its mesial root. The fibres, therefore, are commissural, and constitute a bond of union, called the **commissure of Gudden**, between the internal geniculate bodies.

Lateral Root of the Optic Tract.—The lateral or true visual root of the optic tract is composed of fibres which come—(1) from the lateral half of the retina of its own side; and (2) from the mesial half of the retina of the opposite side, and which have crossed the mesial plane in the optic chiasma. But in addition to the afferent retinal fibres there are a certain number of efferent fibres in the optic tract, fibres which take their origin in the brain and end in the retina. These are distinguished from the afferent retinal fibres by their exceeding fineness.

The fibres of the lateral root of the optic tract end in the superior quadrigeminal body, in the external geniculate body, and in the pulvinar of the optic thalamus. The fibres to the **superior quadrigeminal body** reach it through the superior brachium (p. 493), and for the most part spread out on its surface in the stratum zonale before they sink into its substance, to end in terminal arborisations around its cells. The **corpus geniculatum externum** receives the largest contribution of fibres from the lateral root of the optic tract. These partly sink into its interior and partly spread out over its surface. The former enter into the construction of the curved lamellæ of white matter which traverse this nuclear mass, and to a large extent end in the gray matter which intervenes between these lamellæ. The deep fibres which are not exhausted in this way proceed onwards through the external geniculate body and enter the pulvinar. Of the superficial fibres which spread over the surface of the external geniculate body some dip into its substance and end there, but the majority are carried over it and enter the stratum zonale of the pulvinar. The fibres of the lateral root of the optic tract, which end in the **pulvinar**, therefore reach their destination by passing either over or through the external geniculate body.

Cortical Connexions of the Optic Nerve.—The superior quadrigeminal body, the external geniculate body, and the pulvinar constitute the lower visual centres or terminal nuclei of the visual part of the optic tract. The higher visual centre is placed in the cortex of the occipital lobe of the cerebral hemisphere, and the connexions between this and the lower centres are established by a large strand of fibres which runs in the central white matter of the hinder part of the cerebral hemisphere, and which constitutes the **optic radiation**. The optic radiation is composed both of corticipetal and corticifugal fibres. The former arise as the axons of the cells in the external geniculate body and the pulvinar, around which the retinal fibres end, and they terminate in the cortex of the occipital lobe. The corticifugal fibres take origin in the cortex of the occipital lobe and end in the pulvinar and superior quadrigeminal body (Ferrier and Turner). Thus formed, the optic radiation forms a conspicuous strand (Figs. 397, p. 535; 400, p. 538; 409, p. 550), which, reaching the retrolenticular part of the internal capsule, sweeps backwards into the occipital lobe of the cerebral hemisphere on the outer side of the posterior horn of the lateral ventricle. Its connexions will be studied more fully at a later stage.

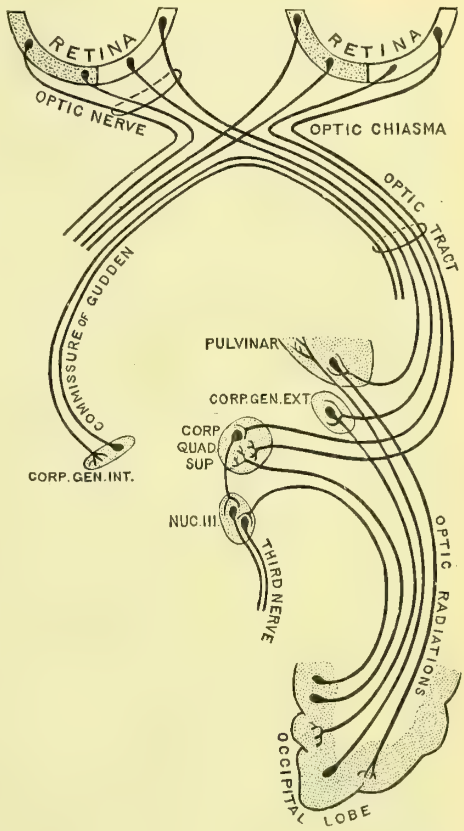


Fig. 380.—Diagram of the Central Connexions of the Optic Nerve and Optic Tract.

Flechsig does not believe that the pulvinar is an internode interposed in the path of the optic nerve as it proceeds towards the visual area of the cerebral cortex. He states that he has not been able to convince himself that any fibres of the optic tract end in the optic thalamus.

Other Connexions of the Lower Group of Visual Centres.—(1) The nuclei of the nerves which supply the muscles which move the eyeball would appear to stand in intimate connexion with the lower group of visual centres. Most probably this connexion is established through the posterior longitudinal bundle. As previously stated, Held believes that axons of certain of the cells of the superior quadrigeminal body enter this tract. (2) Through the mesial fillet, the superior quadrigeminal body is connected with the medulla and cord.

THE PARTS DERIVED FROM THE TELENCEPHALON.

Cerebral Hemispheres.

The cerebral hemispheres form the largest part of the fully-developed brain. When viewed from above they form an ovoid mass, the broadest end of which is directed backwards, and the longest transverse diameter of which will be found in the vicinity of the parts which lie subjacent to the parietal eminences of the cranium. The massive rounded character of the anterior or frontal end of each cerebral hemisphere constitutes a leading human characteristic ; but the hinder or occipital end is narrow and pointed, and is directed somewhat downwards. The two cerebral hemispheres are separated from each other by a deep mesial cleft, termed the great longitudinal fissure.

Great Longitudinal Fissure (fissura longitudinalis cerebri).—In front and behind the great longitudinal fissure passes from the dorsal to the ventral aspect of the cerebral hemispheres, so as to separate them completely from each other. In its middle part, however, the fissure is interrupted and floored by the corpus callosum, a white commissural band, which passes between the hemispheres and

connects them together. The upper surface of the corpus callosum can be displayed by gently drawing asunder the contiguous mesial surfaces of the cerebral hemispheres. The great longitudinal fissure is occupied by a mesial fold of dura mater, termed the falx cerebri, which partially subdivides the part of the cranial cavity allotted to the cerebrum into a right and left chamber.

External Configuration of each Cerebral Hemisphere.—Each cerebral hemisphere presents an external, an internal, and an inferior surface. The *external surface* is convex and is adapted accurately to the deep surface of the cranial vault. The *internal* or *mesial surface* is flat and perpendicular, and bounds the great longitudinal fissure. In great part it is in contact with the falx cerebri; and where that partition is deficient, it is applied to the corresponding portion of the internal surface of the opposite hemisphere. The *inferior surface* is irregular and is adapted to the cranial floor, where it forms the anterior and middle cranial fossæ, and, behind these, to the upper surface of the tentorium cerebelli. Traversing this surface in a transverse direction, nearer the anterior end of the hemisphere than the posterior end, is the stem of the Sylvian fissure. This deep cleft divides the inferior surface into an anterior or *orbital area*, which rests on the orbital plate of the frontal bone, and is consequently concave from side to side, and a more extensive posterior or *tentorial area*, which lies on the floor of the lateral part of the middle cranial fossa and upon the upper surface of the tentorium cerebelli. This surface is arched from before backwards, and looks inwards as well as downwards. In its hinder two-thirds it lies above the cerebellum, from which it is separated by the tentorium cerebelli.

The borders which intervene between these surfaces are the supero-mesial, the superciliary, the infero-lateral, and the internal occipital. The *supero-mesial border*, convex from before backwards, intervenes between the convex external surface and the flat internal surface of the hemisphere. The *superciliary border* is highly arched and separates the orbital surface from the external surface. The *infero-lateral border* marks off the tentorial surface from the external surface. The *internal occipital border* can only be seen in cases where the brain has been hardened *in situ* and faithfully retains the natural form. It extends from the posterior end of the hemisphere towards the hinder extremity of the corpus callosum, and intervenes between the mesial and tentorial surfaces. It is the border which lies along the straight blood sinus, and it therefore occupies the angle which is formed by the attachment of the posterior part of the falx cerebri to the upper surface of the tentorium cerebelli.

The most projecting part of the anterior end of the cerebral hemisphere is called the **frontal pole**, whilst the most projecting part of the hinder end is termed the **occipital pole**. On the under surface of the hemisphere the prominent point of cerebral substance which extends forwards below the Sylvian fissure receives the name of the **temporal pole**. In a well-hardened brain a broad groove is usually present on the inner and lower aspect of the occipital pole of the right hemisphere. This corresponds to the commencement of the right lateral venous sinus. A less distinct groove on the occipital pole of the left hemisphere frequently indicates the commencement of the left lateral sinus. On the tentorial surface, a short distance behind the temporal pole, a well-marked depression is always visible. This corresponds to the high elevation on the anterior surface of the petrous portion of the temporal bone over the superior semicircular canal.

Cerebral Gyri and Sulci.—The surface of the cerebral hemispheres are rendered highly irregular by the presence of convolutions or gyri, separated from each other by intervening furrows of very varying depth, termed sulci or fissures. The surface pattern which is presented by these gyri and sulci is, in its general features, the same in all normal human brains; but when the comparison is pushed into minute detail many differences become manifest, not only in the brains of different individuals, but also in the two cerebral hemispheres of the same individual.

There are two varieties of furrows, viz. complete and incomplete. The **complete fissures** are few in number in the adult brain, and are formed by inwardly-directed infoldings involving the entire thickness of the cerebral wall. They consequently show in the interior of the cerebral cavity or lateral ventricle in the form of internal

elevations on its wall. The complete fissures are the following: (1) the dentate or hippocampal fissure; (2) the anterior part of the calcarine fissure; and (3) a portion of the collateral fissure. The **incomplete fissures** are merely surface furrows of very varying depth, which do not produce any effect on the inner surface of the ventricular wall.

General Structure of the Cerebral Hemispheres.—Each cerebral hemisphere is composed of an outside coating of gray matter, spread in a continuous and uninterrupted layer over its surface, and an internal mass of white matter, which forms for the most part the immediate wall of the ventricular cavity. The gray coating is termed the **cerebral cortex**, and the internal white matter is called the **medullary centre.** Each convolution shows a corresponding structure. On transverse section it is seen to present an external covering of gray cortex, supported by a central core of white matter.

But, in addition to the gray matter on the outside, there are certain large deposits of gray matter embedded in the basal part of each cerebral hemisphere. These cerebral nuclei constitute the **corpus striatum**, and, although to some extent isolated from the gray matter on the surface, it can be easily shown that at certain points they are directly continuous with it.

By means of the convolutions and sulci, the gray matter on the surface of the hemisphere is enormously increased in quantity without unduly adding to the bulk of the organ; and, further, the vascular pia mater, which dips into every fissure, is increased in extent to a like degree. Opportunity is, therefore, afforded to the cortical vessels of breaking up into twigs of exceeding fineness before they enter the substance of the hemisphere. The distribution of blood to the gray cortex is, in this way, equalised and rendered uniform.

Cerebral Lobes and Interlobar Fissures.—Certain of the fissures which traverse the surface of the cerebrum are arbitrarily chosen for subdividing the surface into districts or areas, which are termed lobes. These fissures are termed **interlobar**, and are the following: (1) the fissure of Sylvius; (2) the fissure little Rolando; (3) the parieto-occipital; (4) the calloso-marginal; (5) the collateral; and (6) the limiting sulcus of Reil.

The lobes which are mapped out by these fissures are: (1) the frontal; (2) the parietal; (3) the occipital; (4) the temporal; (5) the insula, or the Island of Reil; (6) the limbic. To these may be added a seventh lobe, in no way related to the interlobar fissures, viz. the olfactory lobe. With the exception of the occipital and olfactory lobes and the insula, this subdivision of the hemisphere presents little morphological or physiological value, and is chiefly adopted for topographical purposes.

Fissure of Sylvius (fissura cerebri lateralis).—This is the most conspicuous fissure on the surface of the cerebral hemisphere. It is composed of a short main stem, from the outer extremity of which three branches or limbs radiate. The **stem** of the Sylvian fissure is placed on the inferior surface of the hemisphere. It begins at the locus perforatus anticus in a depression termed the **vallecula Sylvii.** From this it passes horizontally outwards, forming a deep cleft between the temporal pole and the orbital surface of the frontal lobe. Appearing on the outer surface of the hemisphere at a point called the **Sylvian point**, the Sylvian fissure immediately divides into three radiating branches. These are: (1) the ramus horizontalis posterior; (2) the ramus horizontalis anterior; (3) the ramus anterior ascendens.

The **posterior horizontal limb** is the longest and best marked of the three limbs. It extends backwards, with a slight inclination upwards on the outer surface of the hemisphere for a distance which may vary from about two to three inches. It intervenes between the frontal and parietal lobes which lie above it and the temporal lobe which lies below it, and it finally ends in the region subjacent to the parietal eminence of the cranial wall by turning upwards into the parietal lobe in the form of an *ascending terminal piece.*

The **anterior horizontal limb** extends horizontally forwards in the frontal lobe for a distance of about three-quarters of an inch immediately above and parallel to the posterior part of the superciliary margin of the hemisphere.

The **ascending limb** proceeds upwards, with a slight inclination forwards, into the lower part of the outer surface of the frontal lobe for a distance of about an inch.

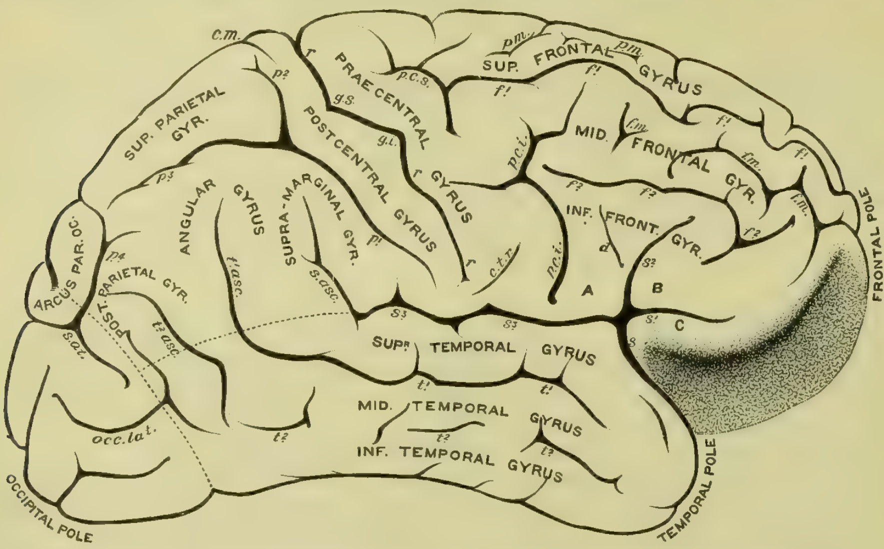


FIG. 381.—GYRI AND SULCI, on the outer surface of the cerebral hemisphere.

f^1.	Sulcus frontalis superior.	r.	Fissure of Rolando.
f^2.	Sulcus frontalis inferior.	g.s.	Superior genu.
f.m.	Sulcus frontalis medius.	g.i.	Inferior genu.
p.m.	Sulcus paramedialis.	d.	Sulcus diagonalis.
A.	Pars basilaris.	t^1.	Superior temporal sulcus (parallel).
B.	Pars triangularis.	t^2.	Inferior temporal sulcus.
C.	Pars orbitalis.	p^1.	Inferior postcentral sulcus.
S.	Sylvian fissure.	p^2.	Superior postcentral sulcus.
s^1.	Anterior horizontal limb (Sylvian fissure).	p^3.	Ramus horizontalis.
s^2.	Ascending limb (Sylvian fissure).	p^4.	Ramus occipitalis.
s^3.	Posterior horizontal limb (Sylvian fissure).	s.o.t.	Sulcus occipitalis transversus.
p.c.i.	Inferior præcentral sulcus.	c.m.	Calloso-marginal sulcus.
p c.s.	Superior præcentral sulcus.	c.t.r.	Inferior transverse furrow.

In many cases the two anterior limbs spring from a common stem of greater or less length, and not infrequently both are replaced by a single anterior limb.

Limiting Sulcus of Reil (sulcus circularis Reilii).—If the lips of the posterior horizontal limb of the Sylvian fissure be widely pulled asunder from each other, the insula or island of Reil will be seen at the bottom. The insular district of the cortex is completely hidden from view when the Sylvian fissure is closed by overlapping portions of the cerebral hemisphere, and, when brought into view in the manner indicated, it is observed to present a triangular outline and to be surrounded by a limiting sulcus, of which three parts may be recognised, viz.: an *upper part*, bounding it above and separating it from the parietal and frontal lobes; a *lower part*, marking it off below from the temporal lobe; and an *anterior part*, separating it in front from the frontal lobe.

Opercula Insulæ.—The overlapping portions of the cerebral substance which cover over the insula are termed the insular opercula, and they form, by the apposition of their margins, the three limbs of the Sylvian fissure. The opercula are four in number and are named: (1) temporal; (2) fronto-parietal; (3) frontal; and (4) orbital. The limbs of the Sylvian fissure cut right through between the different opercula and extend from the exposed surface of the hemisphere to the submerged surface of the insula, and, in this manner, separate the opercula from each other.

The **temporal operculum** extends upwards over the insula from the temporal lobe, and its upper margin forms the lower lip of the posterior horizontal limb of the Sylvian fissure.

The **fronto-parietal operculum** is carried downwards from the parietal and frontal regions over the insula, and its lower margin, meeting the temporal operculum, forms the upper lip of the posterior limb of the Sylvian fissure.

The **frontal operculum** is the small triangular piece of cerebral substance which intervenes between the ascending and anterior horizontal limbs of the Sylvian fissure. It covers over a small part of the anterior portion of the insula, and is sometimes termed the **pars triangularis**.

The **orbital operculum** is, for the most part, on the under surface of the hemisphere. It lies below and to the inner side of the anterior horizontal limb of the Sylvian fissure, and proceeds backwards from the orbital aspect of the frontal lobe over the forepart of the insula.

Development of the Sylvian Fissure and of the Insular District of the Cerebral Hemisphere.—It is only during the latter half of the intrauterine period of development that the opercula take shape and grow over the insula, so as to shut it out from the surface. In its early condition the insula presents the form of a depressed area on the side of the cerebral hemisphere, surrounded by a distinct boundary wall formed by the surrounding more elevated surface of the hemisphere. After a time this depressed area, which is called the Sylvian fossa, assumes a triangular outline, and then the bounding wall is observed to be composed of three distinct parts, viz.: an upper or fronto-parietal, a lower or temporal, and an anterior or orbital part. The rounded angle, formed by the meeting of the upper and anterior portions of the boundary, now becomes flattened, and a short oblique part of the limiting wall, termed the frontal portion, assumes shape in this position. Each of these four portions of the bounding wall of the Sylvian fossa becomes a line of growth, from which an operculum takes origin, and by the approximation of these opercula, as they grow over the surface of the Sylvian fossa, the insula becomes closed in and the limbs of the Sylvian fissure are formed.

Fig. 382.—Three Stages in the Development of the Insula and the Insular Opercula.

A, Right cerebral hemisphere from a fœtus in the latter part of the fourth month of development; B, Right cerebral hemisphere from a fœtus in the fifth month of development; C, Right cerebral hemisphere from a fœtus in the latter part of the eighth month of development.

In C the temporal operculum has been removed, and thus a large part of the insula is exposed.

F.P, Fronto-parietal operculum. F, Frontal operculum. O, Orbital operculum.

The temporal and fronto-parietal opercula make their appearance somewhere about the end of the fifth month of fœtal development, long before the other two opercula show any indication of growth. The temporal operculum grows more rapidly than the fronto-parietal; so that, when

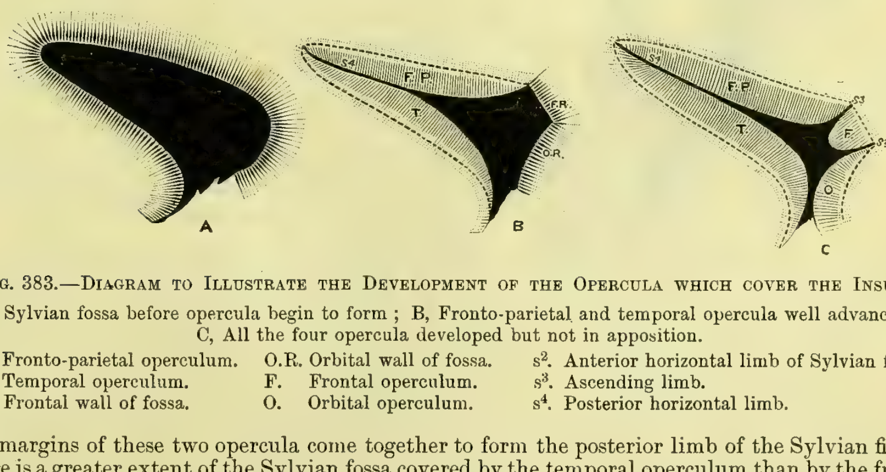


Fig. 383.—Diagram to Illustrate the Development of the Opercula which cover the Insula.

A, Sylvian fossa before opercula begin to form; B, Fronto-parietal and temporal opercula well advanced; C, All the four opercula developed but not in apposition.

F.P. Fronto-parietal operculum.	O.R. Orbital wall of fossa.	s^2. Anterior horizontal limb of Sylvian fissure.
T. Temporal operculum.	F. Frontal operculum.	s^3. Ascending limb.
F.R. Frontal wall of fossa.	O. Orbital operculum.	s^4. Posterior horizontal limb.

the margins of these two opercula come together to form the posterior limb of the Sylvian fissure, there is a greater extent of the Sylvian fossa covered by the temporal operculum than by the fronto-parietal operculum. This accounts for the more oblique direction of the Sylvian fissure in the fœtal brain. But at this stage a growth-antagonism between the two opercula takes place, and in this

the fronto-parietal operculum proves the victor. The contiguous lips of the two opercula become, in the first instance, tightly pressed together, and then, as the upper operculum proves the stronger and the more vigorous in its growth, the posterior limb of the Sylvian fissure becomes gradually depressed until it assumes the inclination characteristic of the adult. It would appear that the opercular growth-antagonism which produces this effect in the human brain does not occur to the same extent, if indeed it occurs at all, in the ape. This is evident from the oblique direction of the posterior limb of the Sylvian fissure in the simian brain. The greater growth energy of the fronto-parietal operculum in the human brain is not confined to the fœtal stage of development, but is carried into the earlier stages of infantile growth, and it is probable that it is due to an extension of that district of the cortex in which the centres for the skilled movements of the upper limbs reside, and also to an extension of Flechsig's parieto-occipital association area.

The orbital and frontal opercula are late in appearing and very tardy in their growth. Indeed, it is only during the course of the first year of infantile life that they come into apposition with each other and with the other two opercula, so as to close in the forepart of the Sylvian fossa and form the anterior limbs of the Sylvian fissure. They do not begin to take shape until more than half of the Sylvian fossa has already been closed by the fronto-parietal and the temporal opercula. The orbital operculum appears first and is much more constant in its growth than the frontal operculum, which indeed frequently fails altogether, and, even when present, shows the greatest amount of variability in the degree to which it is developed.

Variations in the degree of development of the frontal operculum influence greatly the form presented by the two anterior limbs of the Sylvian fissure, between which it lies. When strongly developed, it separates the two Sylvian limbs from each other to such an extent that they assume the appearance of the letter U; when the frontal operculum is less strongly marked, the anterior Sylvian limbs may assume a V form or a Y form. In the latter case, the orbital and the fronto-parietal opercula meet below the frontal operculum to form the stem of the Y. In those cases where the frontal operculum is absent altogether, a single anterior limb of the Sylvian fissure is the result.

The late appearance, the slow growth, the variability of these two opercula, and also the tendency to abortive growth or complete suppression of the frontal operculum, all bespeak the fact that, from a phylogenetic point of view, the frontal and orbital opercula are, comparatively speaking, recent productions in the evolution of the human brain. In the anthropoid ape they are absent, and, consequently, the forepart of the island of Reil is exposed on the surface of the simian brain. The same condition is not at all an uncommon occurrence in the brain of the microcephalic idiot.

Fissure of Rolando (sulcus centralis).—The fissure of Rolando takes an oblique course across the outer convex surface of the cerebral hemisphere and intervenes between the frontal and parietal lobes. Its upper end cuts the supero-mesial border of the hemisphere a short distance behind the mid-point between the frontal and occipital poles, whilst its lower end terminates above the middle of the posterior horizontal limb of the fissure of Sylvius. Its superior extremity, as a rule, turns round the supero-mesial border of the hemisphere, and is then continued backwards for a short distance on the mesial surface. Although, in its general direction, the fissure is oblique, it is very far from being straight. It takes a sinuous course across the hemisphere and makes two bends, which are usually fairly conspicuous, and which are termed the genua. The *superior genu* is placed between the upper and middle thirds of the fissure, and its concavity is directed forwards; the *inferior genu* is situated in front of the superior bend and a short distance lower down. Its convexity is directed forwards. The short portion of the fissure between the two genua is not infrequently very nearly horizontal in direction. The angle which the general direction of the fissure of Rolando makes with the mesial plane is termed the **Rolandic angle**. In the adult brain the average Rolandic angle is 71° 7', and the limits of variation would appear to be 69° and 74°.

FIG. [illegible].—FISSURE OF ROLANDO FULLY OPENED UP, so as to exhibit the interlocking gyri and deep annectant gyrus within it.

When the fissure of Rolando is widely opened up, so that its bottom and its opposed sides may be fully inspected, it will be seen that, in the neighbourhood of the superior genu, the two bounding gyri are dovetailed into each other by a number of interlocking gyri, which do not appear on the surface. Further, two of these, placed on opposite sides of the fissure, are frequently joined across the bottom of the sulcus in the form of a sunken bridge of connexion, which constitutes what is termed a *deep annectant gyrus.* The continuity of the fissure is thus, to some extent, interrupted. This condition is rendered interesting when considered in connexion with the development of the sulcus. The deep interlocking gyri indicate a great exuberance of cortical growth in this situation in the early stages of the development of the fissure; and the presence of the deep annectant gyrus is explained by the fact that the fissure of Rolando generally develops in two pieces, which run into each other to form the continuous sulcus of the adult, viz. a part corresponding to the lower two-thirds, and an upper part, which represents the upper third and which appears at a slightly later date. In certain very rare cases the fissure of Rolando is found to remain double throughout life, through a failure of its two pieces to unite. In such cases the deep annectant gyrus, which is frequently seen at the bottom of the furrow, remains on the surface. Heschl, who examined 2174 cerebral hemispheres, only found this anomaly six times; Eberstaller met with it twice in 200 brains.

FIG. 385.—LEFT CEREBRAL HEMISPHERE, from a fœtus in the early part of the seventh month of development.

p.c.s. Sulcus præcentralis superior.
p.c.i. Sulcus præcentralis inferior.
r^1. Lower part of Rolandic fissure.
r^2. Upper part of Rolandic fissure.
p^1. Inferior postcentral sulcus
p^3. Ramus horizontalis } Intraparietal fissure.
p^4. Ramus occipitalis
e.p. External perpendicular fissure.
t^1. Parallel sulcus.
S. Sylvian fossa.
F.P. Fronto-parietal wall.
F. Frontal wall.
O. Orbital wall.

Parieto-occipital Fissure.—A small part of this fissure appears on the outer face of the cerebral hemisphere. For the most part it is situated on the internal surface. It is customary, therefore, to describe an external parieto-occipital and an internal parieto-occipital fissure. It must be clearly understood, however, that they are directly continuous with each other round the supero-mesial border of the hemisphere. The parieto-occipital fissure intervenes between the parietal and occipital lobes.

The **external parieto-occipital fissure** cuts the supero-mesial border of the hemisphere in a transverse direction at a distance of from one and a half to two inches in front of the occipital pole. It is, as a rule, not more than about a half an inch long, and it is brought to an abrupt termination by an arching convolution, which winds round its extremity and receives the name of **arcus parieto-occipitalis.**

The **internal parieto-occipital fissure** is carried downwards on the inner surface of the hemisphere in a nearly vertical direction as a conspicuous and deep cleft. A short distance behind the hinder end of the corpus callosum its lower end runs into the calcarine fissure.

The parieto-occipital fissure is developed, as a rule, after the manner of a complete fissure. In the fœtal brain it forms a very evident infolding of the cerebral wall. In the adult brain, however, it does not form any eminence on the inner wall of the ventricle, because it does not extend downwards as far as the cavity. The wall of the ventricle during the growth of the hemisphere has thickened to such an extent that the part corresponding to the fissure has become solid.

Collateral Fissure (fissura collateralis).—The collateral sulcus is a strongly-marked fissure on the tentorial face of the cerebral hemisphere. It begins near the occipital pole and extends forwards towards the temporal pole. In its posterior part it is placed below, and parallel to, the calcarine fissure, whilst in front it is separated from the hippocampal or dentate fissure by the hippocampal gyrus, which is the innermost convolution on the tentorial surface of the hemisphere.

In front of the anterior end of the collateral fissure a shallow sulcus turns round the anterior end of the temporal lobe, so as to intervene between the temporal pole and the uncinate or hook-like extremity of the hippocampal convolution. This is the **incisura temporalis**, and it may be regarded as a forward prolongation

of the collateral fissure; at the same time it must be admitted that the two are seldom continuous with each other. The collateral fissure and the incisura temporalis intervene between the limbic and temporal lobes.

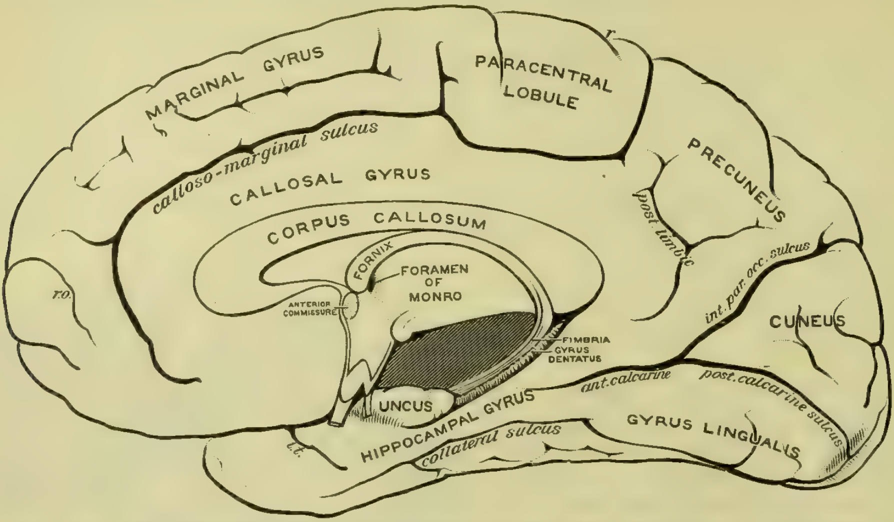


FIG. 386.—THE GYRI AND SULCI ON THE MESIAL ASPECT OF THE CEREBRAL HEMISPHERE. *r*, Fissure of Rolando. *r.o*, Rostral sulcus. *i.t*, Incisura temporalis.

The collateral fissure is developed, as a rule, in three portions—a hinder or occipital, an intermediate, and an anterior or temporal part. These ultimately run into each other and form the continuous fissure. The middle part is usually a complete fissure and responsible for the production of the *eminentia collateralis posterior* in the floor of the trigonum of the lateral ventricle; the temporal part is sometimes a complete fissure, forming when it is so the *eminentia collateralis anterior;* the occipital part is always incomplete.

Calloso-marginal Fissure.—This fissure is a strongly-marked sulcus on the forepart of the mesial surface of the hemisphere. It divides the front portion of the mesial surface into an upper marginal and a lower callosal convolution, and intervenes between the frontal and limbic lobes. Beginning below the fore end of the corpus callosum, close to the locus perforatus anticus, the calloso-marginal fissure curves round in front of the genu of the corpus callosum, and then extends backwards to a point a short distance behind the middle of the mesial surface. It then turns upwards and cuts the supero-mesial border of the hemisphere, immediately behind the upper end of the fissure of Rolando. The relation presented by the two extremities of these fissures is such that they can both be readily recognised either when examined on the outer or mesial aspect of the cerebrum.

The calloso-marginal sulcus is developed in two or three separate pieces, which, as growth proceeds, run into each other and form the continuous fissure. The numerous cases of irregular arrangement met with in connection with this fissure can generally be explained by this interrupted mode of development.

FRONTAL LOBE.—The frontal lobe is the largest of the cerebral lobes. On the outer surface of the hemisphere, it is bounded behind by the fissure of Rolando and below by the posterior horizontal limb of the fissure of Sylvius. On the mesial face it is limited by the calloso-marginal fissure, whilst on the inferior surface of the hemisphere the stem of the Sylvian fissure forms its posterior boundary. It presents an outer surface, a mesial surface, and an inferior or orbital surface.

On the *outer surface of the frontal lobe* the following sulci and gyri may be recognised:—

Sulci:
- Sulcus præcentralis inferior.
- Sulcus præcentralis superior.
- Sulcus paramedialis.
- Sulcus frontalis superior.
- Sulcus frontalis medius.
- Sulcus frontalis inferior.
- Sulcus diagonalis.
- Sulcus fronto-marginalis.

Gyri:
- Gyrus frontalis ascendens or gyrus centralis anterior.
- Gyrus frontalis superior: pars superior; pars inferior.
- Gyrus frontalis medius: pars superior; pars inferior.
- Gyrus frontalis inferior: pars basilaris; pars triangularis; pars orbitalis.

The **inferior præcentral sulcus** consists of a vertical and a horizontal part, and, when developed in a typical manner, it presents a figure like the letter T or F. The *vertical portion* lies in front of the lower part of the fissure of Rolando, whilst the *horizontal part* extends obliquely forwards and upwards into the middle frontal convolution.

The **superior præcentral sulcus** is a short vertical sulcus which lies at a higher level than the inferior præcentral furrow, in front of the upper part of the fissure of Rolando. It is almost invariably connected with the hinder end of the superior frontal sulcus.

The **anterior central convolution** (ascending frontal gyrus) is a long continuous gyrus, which is limited in front by the two præcentral furrows and behind by the fissure of Rolando. It extends obliquely across the hemisphere from the supero-mesial margin above to the posterior horizontal limb of the Sylvian fissure below.

The **superior frontal sulcus** extends forwards in a more or less horizontal direction from the sulcus præcentralis superior.

The **gyrus frontalis superior** is the narrow convolution between the supero-mesial border of the hemisphere and the superior frontal sulcus. It takes a horizontal course to the frontal pole.

The **inferior frontal sulcus** occupies a lower level than the superior frontal furrow. Its hinder end is placed in the angle between the vertical and horizontal parts of the inferior præcentral sulcus, and is not infrequently confluent with one or other of these. It proceeds forwards towards the superciliary margin of the hemisphere and ends a short distance from this in a terminal bifurcation.

The **gyrus frontalis medius** is the name given to the broad convolution which lies between the superior and inferior frontal sulci.

The **gyrus frontalis inferior** is that portion of the outer surface of the frontal lobe which is placed in front of the inferior præcentral sulcus and below the inferior frontal sulcus. The inferior frontal convolution is cut into three pieces by two anterior limbs of the Sylvian fissure. These are termed the pars basilaris, the pars triangularis, and the pars orbitalis.

The **pars basilaris** is that part which lies between the vertical limb of the inferior præcentral sulcus and the ascending limb of the Sylvian fissure. It forms the anterior part of the fronto-parietal operculum, and it is traversed in an oblique direction by a shallow but constant furrow, termed the **sulcus diagonalis**. The **pars triangularis** is simply another name for the frontal operculum. It is triangular in form, and lies between the anterior ascending and the anterior horizontal limbs of the Sylvian fissure. The **pars orbitalis** is placed below the anterior horizontal limb of the Sylvian fissure.

The inferior frontal convolution possesses a special interest on account of the localisation within it, on the left side, of the speech centre. From it, also, the front part of the fronto-parietal and the whole of the frontal operculum are developed. This opercular development in connexion with the inferior frontal gyrus constitutes a leading point of difference between the brain of man and that of the ape. Even in the highest ape the inferior frontal convolution is not opercular. The frontal operculum is not present and the anterior part of the insula is exposed on the surface. Probably the excess of growth which determines the formation of the frontal operculum in man has some connexion with the development of the speech centre.

The **sulcus paramedialis** is the term applied to a series of short irregular depressions or furrows, arranged longitudinally, close to the supero-mesial border of the hemisphere. These rudimentary sulci partially subdivide the superior frontal convolution into an upper and a lower part, and they are of interest in so far that they are never developed in the ape, and are deeper and better marked in the higher types of human brain.

The **sulcus frontalis medius** (Eberstaller) proceeds horizontally forwards in the forepart of the middle frontal convolution, so as to subdivide it into an upper and a lower part. When the furrow reaches the superciliary margin of the hemisphere it bifurcates, and its terminal branches spread out widely and constitute a transverse furrow, called the fronto-marginal sulcus. The sulcus frontalis medius is only found in man and the anthropoid apes. It is not present in any of the lower apes.

Owing to the subdivision of the superior and middle frontal convolutions in the manner indicated, the typical arrangement of the convolutions in the anterior part of the outer surface of the frontal lobe is in five horizontal tiers, and not in three tiers, as formerly described.

As a rule, the sulci on the outer surface of the frontal lobe during the process of development appear in the following order: (1) sulcus præcentralis inferior; (2) sulcus frontalis inferior; (3) sulcus præcentralis superior and sulcus frontalis superior; (4) sulcus frontalis medius; (5) sulcus paramedialis. This gives an indication of the relative morphological importance of these sulci.

On the *mesial aspect of the frontal lobe* there is an elongated more or less continuous convolution, called the **gyrus marginalis**. It lies between the supero-mesial margin of the hemisphere and the calloso-marginal fissure. In the forepart of this gyrus one or two curved sulci are usually present. They are termed the **sulci rostrales**. The posterior part of the marginal convolution is more or less completely cut off from the portion which lies in front. This part is called the **paracentral lobule**, and into it the upper end of the fissure of Rolando is prolonged as it turns over the supero-mesial border of the hemisphere.

On the *orbital aspect of the frontal lobe* there are two sulci, viz. the olfactory and the orbital.

The **olfactory sulcus** is a straight furrow which runs parallel to the mesial border of the hemisphere. It is occupied by the olfactory tract and bulb, and it cuts off a narrow strip of the orbital surface close to the mesial border, which receives the name of **gyrus rectus**.

The **orbital sulcus** is a composite furrow which assumes many different forms. As a general rule it presents a shape similar to that of the letter H, and is then composed of three parts, viz. an external limb, an internal limb, and a transverse limb. The **external limb** (sulcus orbitalis externus) curves round the orbital part of the inferior frontal convolution, so as to limit it on this aspect of the brain. The **internal limb** (sulcus orbitalis internus) is frequently broken up into two pieces. It marks off a convolution between itself and the olfactory sulcus, called the **gyrus orbitalis internus**. The **transverse limb** (sulcus orbitalis transversus) takes a curved course between the internal and external limbs. The district in front is termed the **gyrus orbitalis anterior**, and that behind the **gyrus orbitalis posterior**. The latter, in its outer part, corresponds with the orbital operculum.

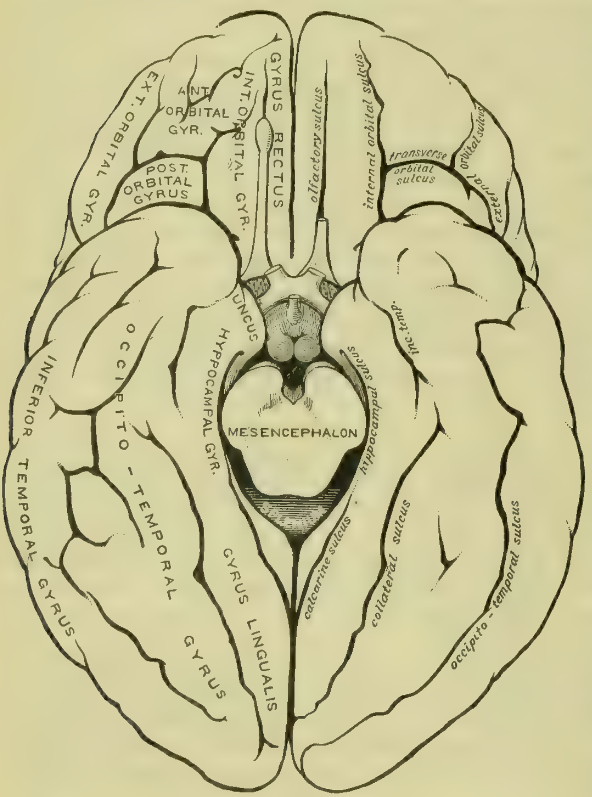


FIG. 387.—GYRI AND SULCI on the tentorial and orbital aspects of the cerebral hemispheres.

PARIETAL LOBE.—The parietal lobe forms a considerable part of the external surface of the cerebral hemisphere, and it also appears on the inner surface in the form of the præcuneus or the quadrate lobule. *In front*, it is bounded by the fissure of Rolando, which separates it from the frontal lobe. *Below*, it is limited in its forepart by the posterior horizontal limb of the fissure of Sylvius. Behind the upturned end of this fissure the surface of the parietal

lobe is continuous inferiorly with that of the temporal lobe, and an arbitrary line drawn backwards on the surface of the brain, in continuation of the horizontal part of the posterior limb of the Sylvian fissure, is taken as its inferior limit. *Posteriorly*, it is separated from the occipital lobe at the supero-mesial border of the hemisphere by the external parieto-occipital fissure. Below this fissure the surface of the parietal lobe is continuous with that of the occipital lobe; and an arbitrary line drawn across the outer surface of the hemisphere, from the extremity of the external parieto-occipital fissure to an indentation on the infero-lateral border of the hemisphere, termed the **præoccipital notch**, may be regarded as furnishing a posterior limitation.

The præoccipital notch is, as a rule, only visible in brains that have been hardened *in situ*. It is placed on the infero-lateral border of the hemisphere, about an inch and a half in front of the occipital pole, and is produced by a vertical fold or wrinkle of the dura mater on the deep aspect of the parieto-mastoid suture, and immediately above the highest part of the lateral blood-sinus.

There is great variability in the degree to which this fold of dura mater projects in different individuals. In the child it is always very salient, and often produces a deep cleft in the brain, but as the full size of the cranium is gradually attained it becomes much less projecting. In the young skull two or three such folds in this locality are usually apparent. Related to the præoccipital notch there are likewise some cerebral veins which turn round the infero-lateral margin of the hemisphere to join the lateral blood-sinus.

On the *mesial surface of the hemisphere* the parietal lobe is represented by the **præcuneus or quadrate lobule.** This district, which is somewhat quadrilateral in form, lies between the upturned end of the calloso-marginal sulcus and the internal parieto-occipital fissure. It is imperfectly separated below from the limbic lobe by a somewhat variable furrow called the **post-limbic sulcus.**

The gyri and sulci, on the *outer surface of the parietal lobe*, are the following:—

- Sulci
  - Sulcus intraparietalis (of Turner).
    - Sulcus postcentralis inferior.
    - Sulcus postcentralis superior.
    - Ramus horizontalis.
    - Ramus occipitalis.
  - Upturned ends of—
    - (*a*) Sylvian fissure.
    - (*b*) Parallel fissure.
    - (*c*) Second temporal fissure.
- Gyri
  - Gyrus ascendens parietalis or gyrus postcentralis.
  - Gyrus parietalis superior.
  - Gyrus parietalis inferior
    - Gyrus supramarginalis.
    - Gyrus angularis.
    - Gyrus postparietalis.

The **intraparietal sulcus** (of Turner) is a composite furrow, and is built up of four originally distinct factors. Two of these, termed the sulcus postcentralis inferior and the sulcus postcentralis superior, take a more or less oblique course across the hemisphere, and are most frequently united into one continuous fissure. The other two factors are placed horizontally, one behind the other, and are termed the ramus horizontalis and the ramus occipitalis.

The **sulcus postcentralis inferior** lies behind the lower part of the fissure of Rolando, whilst the **sulcus postcentralis superior** occupies a similar position in relation to the upper part of that fissure. When confluent they form a long, continuous fissure, which stretches across the hemisphere behind the fissure of Rolando and parallel to it.

The **ramus horizontalis** is continuous, as a rule, with the upper end of the sulcus postcentralis inferior, and extends backwards, with a slight inclination upwards between the superior parietal gyrus, which lies above it, and the inferior parietal gyrus, which is placed below it. With the two confluent postcentral sulci it presents a figure like the letter ⊣ placed on its side.

The **ramus occipitalis** is a curved sulcus which bounds externally the arcus parieto-occipitalis, or, in other words, the arching convolution which surrounds the external parieto-occipital fissure. The ramus occipitalis lies behind the ramus horizontalis, and is generally linked on to it; less frequently it is separate. The posterior end of the ramus occipitalis enters the occipital lobe, and, behind the arcus parieto-occipitalis, bifurcates into two widely-spread-out branches. These form a short transverse fissure in the occipital lobe, termed the **sulcus occipitalis transversus.**

In the human brain the intraparietal sulcus is usually developed in four separate pieces, corresponding to the four portions of the fissure which have been described as being present in the adult brain. The sulcus postcentralis inferior appears first (somewhere about the end of the sixth month), then the ramus occipitalis and the ramus horizontalis; last of all the sulcus postcentralis superior comes into view. The further development of the sulcus consists in the running together of these early pieces. This takes place in different ways, and not infrequently union fails at one or more points, and thus a great variety of combinations may be noted in different individuals; indeed, it may be said that every possible kind of combination may be met with. The most common form which the fissure assumes, however, is that in which all its factors have become confluent and one continuous furrow results. When such an intraparietal furrow is widely opened up, certain deep annectant gyri, which cross the bottom of the sulcus,

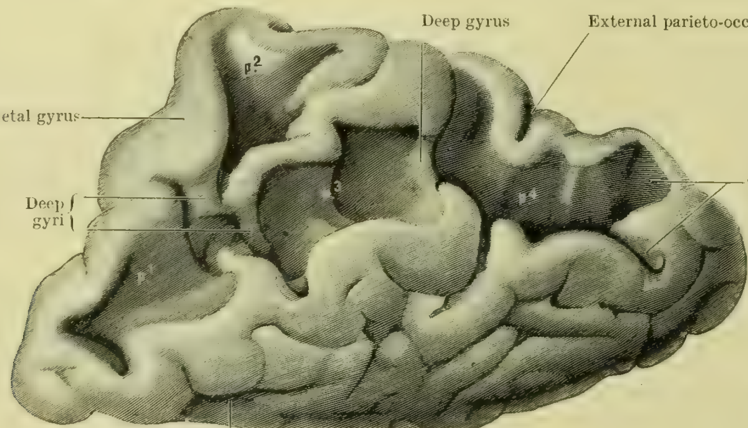


FIG. 388.—THE INTRAPARIETAL SULCUS FULLY OPENED UP, so as to show its several parts and the deep annectant gyri intervening between them.

p^1. Sulcus postcentralis inferior.
p^2. Sulcus postcentralis superior.
p^3. Ramus horizontalis.
p^4. Ramus occipitalis.

come into view. These interrupt the sulcus at the points of union between its several pieces and indicate its original multiple formation.

There is reason to believe that three of the elements of the human intraparietal sulcus, viz. the sulcus postcentralis inferior, the ramus horizontalis, and the ramus occipitalis, are disrupted portions of the primitive single continuous fissure which is seen in certain of the lower apes (Cebus), whilst one, the sulcus postcentralis superior, is a superadded element.

There is a strong analogy between the postcentral sulcus, the fissure of Rolando, and the præcentral sulcus. They form a group of radial sulci on the outer surface of the fœtal cerebrum above the Sylvian region. The fissure of Rolando makes its appearance first, then the præcentral sulcus, and, lastly, the postcentral sulcus. Each assumes shape in the first instance in two pieces, viz. an upper and lower. The two pieces of the fissure of Rolando join early, and only in very rare instances remain separate; the two pieces of the postcentral furrow usually join, but in 19 per cent of cerebral hemispheres they remain separate; the two pieces of the præcentral furrow, as a rule, remain separate and distinct.

The **sulcus transversus occipitalis**, or bifurcated extremity of the ramus occipitalis, is very generally believed to be the representative in the human brain of the conspicuous "Affenspalte" in the cerebrum of the ape. It is very doubtful if this is the case; and it is also doubtful if there is, as a rule, in the adult human brain any representative of this simian fissure. The "Affenspalte" is a complete fissure, and every observer is agreed that in the human fœtal brain its equivalent is a deep infolding of the hemisphere wall which takes place in this locality, and which receives the name of the **fissura perpendicularis externa**. In the course of development this fœtal fissure disappears; it is a transitory fissure and becomes completely wiped out from the hemisphere surface. The only connexion which exists between it and the sulcus occipitalis transversus consists in the fact that the latter, at a later period, becomes developed on the ground occupied by the transitory fissura perpendicularis externa.

The upturned ends of the fissure of Sylvius, of the first temporal or parallel sulcus, and of the second temporal sulcus ascend for a short distance, one behind the other, into the inferior parietal gyrus.

The intraparietal sulcus maps out three districts or gyri on the external surface of the parietal lobe, viz. the ascending parietal convolution, the superior parietal gyrus, and the inferior parietal gyrus.

The **posterior central convolution** (ascending parietal convolution) is a long gyrus which extends obliquely across the hemisphere from the supero-mesial border above

to the Sylvian fissure below. It is bounded in front by the fissure of Rolando and behind by the superior and inferior postcentral sulci.

The **superior parietal gyrus** is the area of cerebral cortex which lies between the supero-mesial border of the hemisphere above and the ramus horizontalis below. In front it is bounded by the superior postcentral sulcus, whilst behind it is connected with the occipital lobe by the arcus parieto-occipitalis. It is continuous round the supero-mesial border with the præcuneus.

The **inferior parietal gyrus** lies below the ramus horizontalis and the ramus occipitalis and behind the inferior præcentral sulcus. It is more or less directly continuous with the occipital lobe behind and the temporal lobe below. From before backwards it presents three arching convolutions, viz. the supra-marginal, the angular, and the postparietal. The **supramarginal convolution** is bent round the upturned end of the posterior limb of the Sylvian fissure, and stands in continuity behind and below this, with the first temporal gyrus. The **angular convolution** arches over the upturned end of the parallel sulcus and becomes continuous with the second temporal convolution. The **postparietal convolution** winds round the upturned end of the second temporal sulcus and runs into the third temporal gyrus.

Occipital Lobe.—The occipital lobe forms the hinder pyramidal part of the cerebral hemisphere; and although very imperfectly mapped off from the temporal and parietal lobes, which lie in front of it, it is nevertheless one of the most natural subdivisions of the cerebral hemisphere. It is not developed in the brain of the quadruped. Man and the ape alone possess a well-marked occipital lobe, and it may be defined as being that part of the hemisphere which encloses the posterior horn of the lateral ventricle. Being pyramidal in form, it presents three surfaces and an apex or occipital pole. On the mesial aspect of the hemisphere it is separated from the parietal lobe (*i.e.* the præcuneus) by the internal parieto-occipital fissure. On the tentorial or inferior surface it is not marked off in any way from the temporal lobe and the limbic lobe, which lie in front of it. It is necessary, therefore, on this aspect to employ an arbitrary line of demarcation; one which extends from the præoccipital notch on the infero-lateral border of the hemisphere to the isthmus of the limbic lobe (*i.e.* the narrow part of the limbic lobe immediately below the hinder end of the corpus callosum) will serve the purpose. On the external surface the external parieto-occipital fissure, and an arbitrary line from this to the præoccipital notch, may be regarded as separating the occipital from the parietal and temporal lobes. The upturned end of the second temporal sulcus may lie in the course of this line.

In the ape, in which the occipital lobe is better marked than in man, there is a very definite boundary on both the mesial (internal parieto-occipital fissure) and the external aspect of the hemisphere ("Affenspalte"); and in the human fœtus there is, in most cases, a fissural infolding on each of the three aspects of the hemisphere marking off the occipital lobe in the most definite manner. The internal infolding is retained as the internal parieto-occipital fissure; the external infolding, or the fissura perpendicularis externa, is the representative of the "Affenspalte" of the ape, and it gradually disappears from the surface of the brain; the inferior infolding, which is connected with the mid-collateral fissure, is also to some extent transitory.

On the *mesial aspect of the occipital lobe* we find: (1) the calcarine fissure, (2) the cuneus, and (3) the gyrus lingualis.

The **calcarine fissure** begins on the occipital pole by a bifurcated extremity, which lies in the groove which is formed on this part of the brain by the lateral sinus. From this it pursues a slightly arched course forwards, and ends by cutting into the limbic lobe immediately below the splenium or thickened hinder margin of the corpus callosum. The calcarine fissure is joined by the internal parieto-occipital fissure at a point somewhat nearer its anterior than its posterior extremity. Together, the two fissures present a ≺-shaped figure. Between the two limbs of the Y is placed the cuneus.

If the calcarine and internal parieto-occipital fissures are opened up so as to expose the bottom in each case, three well-marked deep or submerged annectant gyri will usually be displayed. One of these, the best marked, called the **gyrus cunei**, marks off the parieto-occipital from the calcarine fissure and joins the cuneus with the limbic lobe. In the chimpanzee and in the lower apes the gyrus cunei is on the surface, and there is no communication between the two fissures; in the orang, gibbon, and microcephalic idiot, it may either be submerged or on the

surface. The second deep annectant gyrus, termed the **anterior cuneo-lingual**, crosses the bottom of the calcarine fissure a short distance behind the point where it is joined by the parieto-occipital fissure, and divides it into an anterior and a posterior part. The **anterior calcarine fissure** is slightly longer and much deeper than the posterior part. It includes the whole of the stem of

FIG. 389.—INTERNAL PARIETO-OCCIPITAL AND THE CALCARINE FISSURES FULLY OPENED UP, so as to show the deep annectant gyri marking off the several elements of the ≺-shaped system.

the Y-shaped fissural arrangement and extends backwards for a short distance into the cuneus. It is the complete part of the fissure and gives rise to an elevation on the inner wall of the posterior horn of the lateral ventricle, to which the name of calcar avis or hippocampus minor is given. The **posterior calcarine fissure** is shallower and is usually interrupted by the third deep annectant gyrus, viz. the **posterior cuneo-lingual**; this divides it into two parts, of which the

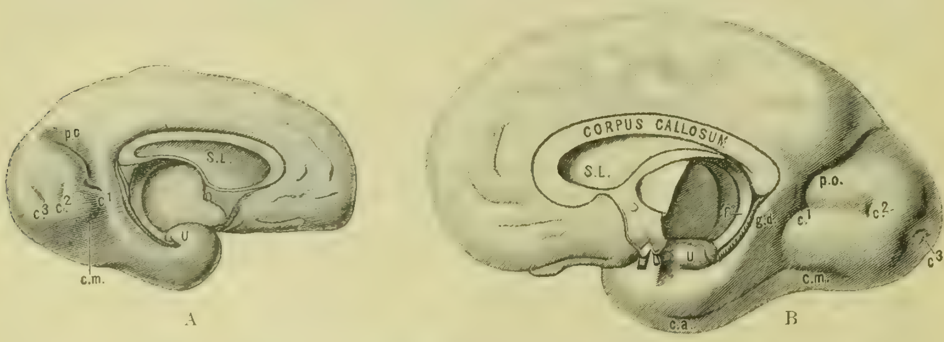


FIG. 390.—DEVELOPMENT OF THE PARIETO-OCCIPITAL AND THE CALCARINE FISSURES.

A, Mesial aspect of a left cerebral hemisphere of a fœtus approaching the end of the fifth month of development; B, Mesial aspect of a right cerebral hemisphere of a fœtus in the beginning of the seventh month of development.

S.L. Septum lucidum.
f. Fornix.
U. Uncus.
g.d. Gyrus dentatus.
p.o. Parieto-occipital fissure.
c^1. Anterior calcarine fissure.
c^2., c^3. Two parts of posterior calcarine fissure.
c.a. Anterior collateral fissure.
c.m. Mid-collateral fissure.

hinder is little more than the bifurcated extremity of the fissure. Very frequently this deep gyrus reaches the surface, and then the hinder end of the sulcus is completely cut off. The posterior calcarine fissure is not a complete fissure.

When the manner in which the calcarine fissure is developed is studied, the various appearances which come into view when the bottom of the adult fissure is inspected receive the fullest explanation. The anterior calcarine fissure is formed very early as an infolding of the wall of

the cerebral fissure. It is apparently the only part which is developed in the ape, and often also it is the only part which is present in the brain of the microcephalic idiot. It is not uncommon, in the normal cerebrum, to find that it presents an ape-like form and is completely cut off from the posterior part of the fissure. The posterior calcarine fissure is a secondary formation. It appears much later, and usually in two pieces, which run together and then join the anterior calcarine fissure. The points of union are indicated in the adult by the two cuneo-lingual deep gyri. The posterior calcarine fissure is a purely human characteristic; it is not found in any ape, and is usually absent also in the more intense forms of microcephalic idiocy.

The **cuneus** is the wedge-shaped or triangular district, on the mesial aspect of the occipital lobe, which lies between the internal parieto-occipital and calcarine fissures.

The **gyrus lingualis** is a well-marked convolution between the calcarine fissure above and the posterior part of the collateral fissure below, which stretches forwards from the occipital pole. Anteriorly, it becomes very narrow and joins the hippocampal part of the limbic lobe. It lies partly on the mesial surface and partly on the tentorial surface of the occipital lobe.

On the *tentorial surface of the occipital lobe* there is only one convolution, viz. the posterior part of the **occipito-temporal gyrus**. It proceeds continuously forwards into the temporal lobe on the outer side of the collateral fissure, and is bounded externally by the **occipito-temporal sulcus**, a furrow which is rarely continuous, but is usually represented by a series of detached pieces.

There are two well-marked sulci on the *external surface of the occipital lobe*, viz. the sulcus occipitalis transversus and the sulcus occipitalis lateralis. The **sulcus occipitalis transversus** extends transversely across the upper part of the lobe, behind the arcus parieto-occipitalis. As already explained, it is the terminal bifurcation of the ramus occipitalis of the intraparietal sulcus. The **sulcus occipitalis lateralis** is a short horizontal furrow, which divides the outer surface of the lobe into an upper and a lower area of very nearly equal extent. These areas are connected by superficial annectant gyri with the parietal and temporal lobes.

Temporal Lobe.—The temporal lobe lies behind the stem and below the posterior horizontal limb of the Sylvian fissure. It is somewhat pyramidal in form, and presents an upper, an outer, and a tentorial surface, with a free projecting apex or pole. Above, it is bounded by the posterior horizontal limb of the fissure of Sylvius, together with the artificial line which is drawn backwards from this. On the tentorial face it is separated from the hippocampal part of the limbic lobe by the collateral fissure, whilst behind it is marked off from the occipital lobe by the artificial lines already described. The temporal pole projects forwards on the under surface of the brain beyond the stem of the Sylvian fissure. It should be noticed that the recurved end of the hippocampal part of the limbic lobe (uncus), which lies to the inner side of the temporal pole, does not extend so far forwards as the latter, and is separated from the pole by the incisura temporalis. This sulcus may be regarded as the connecting link between the anterior end of the collateral fissure and the inferior limiting sulcus of Reil. The importance of this connexion is evident when we recollect that, strictly speaking, the inferior limiting sulcus of Reil is the true upper limit of the temporal lobe.

The *upper or opercular surface of the temporal lobe* is turned towards the island of Reil and the fronto-parietal operculum. The fissure of Sylvius must, therefore, be widely opened up to expose it. For the most part the surface is smooth, but towards the back part there are a few transverse furrows, which separate two or three weakly-expressed gyri.

The anterior transverse gyrus is much more strongly expressed in the fœtal than in the adult brain. It appears in the early part of the seventh month, and is only subsequently completely hidden within the Sylvian fissure. The fact of the auditory centre being localised in this region of the temporal lobe makes this fact of interest.

On the deep surface of the temporal pole there are also a few feeble furrows.

On the *outer surface of the temporal lobe* there are two horizontal sulci, called respectively the first temporal or parallel and the second temporal sulcus.

The **parallel sulcus** is a long, continuous, and deep fissure, which begins near the temporal pole and proceeds backwards below the posterior limb of the Sylvian

fissure. Its hinder end turns upwards into the parietal lobe and is surrounded by the angular gyrus. The **second temporal sulcus** is placed midway between the parallel sulcus and the infero-lateral border of the hemisphere. It is very rare to find it in the form of a continuous cleft; usually it is broken up into several isolated pieces, one behind the other. Its hinder part, which turns upwards into the parietal lobe, lies close to the artificial line of demarcation between the occipital and parietal lobes, and is surrounded by the postparietal gyrus.

By the two temporal sulci the outer surface of the temporal lobe is mapped out into three tiers of horizontal convolutions, which are termed the **first**, **second**, and **third temporal gyri**.

On the *tentorial surface of the temporal lobe* there is one fissure, termed the occipito-temporal sulcus. The **occipito-temporal sulcus** lies to the outer side of the collateral fissure and close to the infero-lateral margin of the hemisphere. It runs in an antero-posterior direction, and is not confined to the temporal lobe, but extends backwards towards the occipital pole. It is usually broken up into two or more separate pieces.

The **occipito-temporal convolution** is situated between the collateral fissure and the occipito-temporal sulcus. It extends from the occipital pole behind to the temporal pole in front.

The narrow strip of surface on the outer side of the occipito-temporal sulcus is continuous, round the infero-lateral margin of the hemisphere, with the third temporal convolution on the outer surface of the cerebrum, and may be reckoned as a part of it.

The three temporal convolutions and the occipito-temporal convolutions run into each other at the temporal pole.

Island of Reil or Insula.—The insula is a triangular and somewhat bulging field of cerebral cortex, which lies on a deeper plane than the general surface of the hemisphere and is hidden from view by the four opercula which overlap it. It is circumscribed by a limiting sulcus (sulcus circularis), already described, and its dependent apical part, which is directed downwards, is in close relation to the anterior perforated spot and the Sylvian vallecula. Here the limiting sulcus is absent and the gray matter on the surface of the insula passes continuously into the anterior perforated spot. The place of transition is called the **limen insulæ**.

The insula is divided into several diverging convolutions by a series of radiating sulci. Of the latter, one, which presents the same direction and lies in the same plane as the fissure of Rolando, receives the name of the **sulcus centralis insulæ** (Fig. 382, C, p. 515). It divides the insula into an anterior *frontal part* and a posterior *parieto-limbic part*.

Limbic Lobe.—This lobe is seen on the mesial surface of the hemisphere in the form of an elongated ring-like convolution, the extremities of which approach closely to each other at the locus perforatus anticus. These extremities are connected by the roots of the olfactory tract, and in this manner the limbic ring may be considered to be closed. The upper part of the limbic lobe is placed in intimate relation to the extremities and upper surface of the corpus callosum, and receives the name of callosal convolution or gyrus fornicatus. The lower portion of the lobe is termed the hippocampal convolution and forms the inner part of the tentorial surface of the hemisphere. The continuity between the hippocampal gyrus and the callosal convolution is established below the hinder end of the corpus callosum by a narrow portion of the limbic lobe, called the isthmus. From this point the hippocampal convolution extends forwards towards the temporal pole. Finally, on the side of the crus cerebri, the hippocampal gyrus is folded back on itself and ends in a recurved hook-like extremity, called the uncus. The uncus does not reach so far forwards as the temporal pole.

The **callosal convolution** begins below the anterior end of the corpus callosum at the locus perforatus anticus, and, winding round the genu of the corpus callosum, it is continued backwards on its upper surface to its hinder thickened extremity or splenium. Curving round this, it becomes greatly narrowed through the calcarine fissure cutting into it. This narrow part is termed the **isthmus**, and constitutes the link of connexion between the callosal gyrus and the hippocampal gyrus. The

callosal gyrus is separated from the marginal convolution by the calloso-marginal fissure, and behind this it is imperfectly marked off from the præcuneus by the post-limbic sulcus. The furrow which separates it from the corpus callosum is termed the **callosal sulcus.**

The **hippocampal convolution** is bounded on the outer side by the anterior part of the collateral fissure, and in front of this by the incisura temporalis, which separates its hooked extremity, or **uncus,** from the temporal pole. On the inner side it is limited by the hippocampal or dentate fissure, whilst posteriorly it is divided into two parts by the anterior extremity of the calcarine fissure. Of these, the upper is the isthmus, which connects it with the callosal gyrus, whilst the lower portion brings it into continuity with the gyrus lingualis. The surface of the hippocampal convolution is covered by a white reticular stratum of fibres, termed the *substantia reticularis alba.*

Gyrus Dentatus and the Fimbria.—If the dentate fissure, which lies along the inner side of the hippocampal convolution, be opened up, the gyrus dentatus and the fimbria, lying side by side, will be brought into view (Fig. 386, p. 518).

The **fimbria** is simply a portion of the posterior pillar of the fornix prolonged into this region. It is a conspicuous band of white matter, which presents a prominent free border. In front it runs into the recurved extremity of the uncus, whilst, if traced backwards, it will be seen to curve upwards behind the posterior end of the optic thalamus and become continuous with the posterior pillar of the fornix below the hinder part of the corpus callosum.

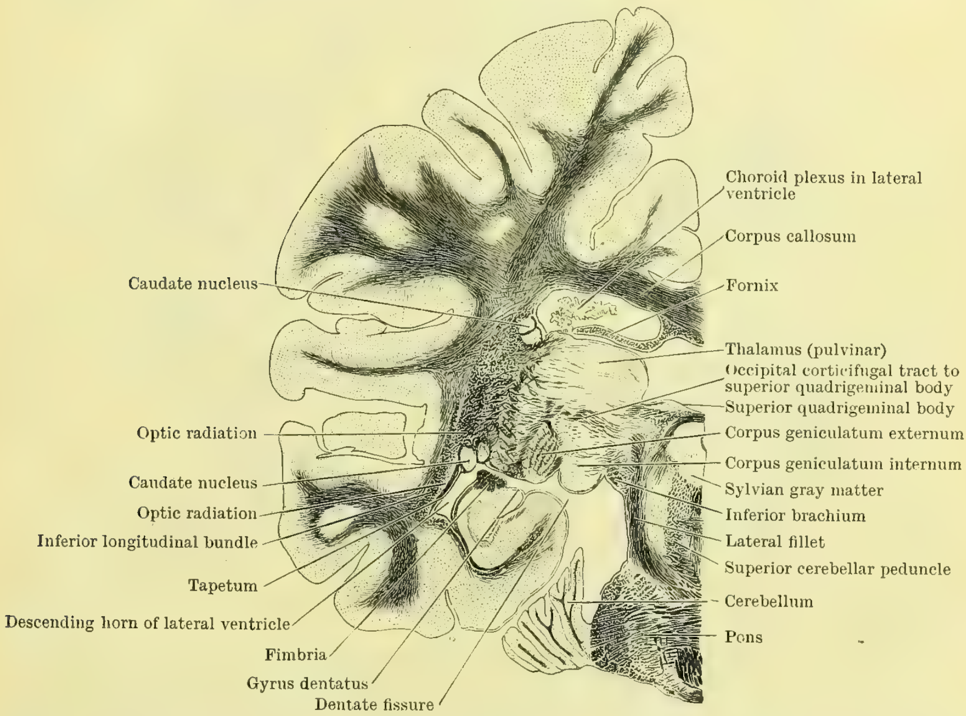


FIG. 391.—CORONAL SECTION THROUGH THE LEFT SIDE OF THE CEREBRUM, MESENCEPHALON, AND PONS, IN THE REGION OF THE PULVINAR OF THE THALAMUS AND THE CORPORA GENICULATA (Chimpanzee; Weigert-Pal specimen).

The **gyrus dentatus** is the free edge of gray matter which is placed between the fimbria and the deep part of the upper surface of the hippocampal convolution. The groove between it and the fimbria is termed the **fimbrio-dentate sulcus,** whilst the furrow between it and the hippocampal convolution forms the bottom of the **dentate fissure.** The dentate gyrus is notched along the margin, whilst its surface is scored by numerous parallel and closely-placed transverse grooves. It begins behind in the region of the splenium or thickened posterior margin of the corpus callosum, and is carried forwards into the cleft of the uncus. From this it emerges

in the form of a delicate band, which crosses the surface of the recurved part of the uncus in a transverse direction, thereby constituting the *frenulum Giacomini*.

The **dentate fissure** is a complete fissure, and the elevation on the ventricular wall which corresponds to it is called the hippocampus major. It begins behind the splenium of the corpus callosum, where it is continuous with a shallow part of the callosal fissure, and it proceeds forwards between the gyrus dentatus and the hippocampal convolution. Its anterior end is enclosed within the uncus.

When coronal sections are made through the callosal part of the limbic lobe and the subjacent corpus callosum, the cortical gray matter is seen to be reflected from the bottom of the callosal fissure in the form of an exceedingly fine layer, which forms a thin coating for the upper surface of the corpus callosum. In the midst of this certain delicate strands of longitudinal fibres, the **striæ longitudinales**, are embedded, and, with the gray matter associated with them, they represent an aborted or vestigial convolution, termed the **gyrus supracallosus**. This gyrus is continuous with the gyrus dentatus round the hinder margin of the corpus callosum.

Olfactory Lobe.—The olfactory lobe is small and rudimentary in the human brain. It is described by His as consisting of a **posterior lobule**, which may be said to correspond with that part of the hemisphere which is named the locus perforatus anticus, and an **anterior lobule**, composed of: (1) the olfactory bulb and tract, with the two roots of the latter; (2) the trigonum olfactorium; and (3) the area of Broca.

The **olfactory tract** is a narrow, white, prismatic band, which expands anteriorly into a swollen bulbous extremity, termed the **olfactory bulb**. Both the tract and the bulb lie upon the olfactory sulcus on the orbital surface of the frontal lobe, whilst the inferior surface of the bulb rests on the cribriform plate of the ethmoid bone, and receives the numerous olfactory nerves which reach it through the foramina in that part of the cranial floor.

Posteriorly, the olfactory tract divides into two diverging roots. The **mesial root** curves abruptly inwards behind the area of Broca, into which some of its fibres pass, and is continued into the extremity of the callosal gyrus. The **lateral root** runs backwards and outwards over the outer part of the locus perforatus anticus, and gradually disappears from view. In animals, in which the olfactory apparatus is better developed than in man, it may be traced into the uncinate extremity of the hippocampal convolution (Fig. 325, p. 439).

The **trigonum olfactorium** or olfactory tubercle is the small triangular field of gray matter which occupies the interval between the roots of the olfactory tract at the point where they begin to diverge. Some fibres from the posterior end of the olfactory tract enter the trigonum, and, in certain cases, these constitute a more or less distinct **middle root**.

The **area of Broca** lies in front of the curved mesial root of the olfactory tract, and is continuous with the commencement of the callosal gyrus.

Rhinencephalon and Pallium.—The cerebral hemisphere is composed of two naturally distinct parts—the rhinencephalon and the pallium—in addition to the corpus striatum. The rhinencephalon consists of the olfactory bulb and its peduncle, together with the anterior perforated space and anterior part of the uncinate gyrus, the gyrus subcallosus, septum lucidum, and hippocampus with its *adnexa*. The pallium includes the rest of the hemisphere, exclusive of the corpus striatum (Elliot Smith).

There can be little doubt that the gyrus supracallosus represents a wasted portion of the hippocampus. In monotremes and marsupials the hippocampus occupies a corresponding position, but, with the greater development of the corpus callosum in higher mammals, atrophy and stretching occur, and the structure is reduced to a vestigial condition (Elliot Smith).

In their phylogenetic evolution the rhinencephalon and the pallium appear to develop more or less independently of each other. In certain cases the former atrophies, whilst the pallium attains a high degree of development (*e.g.* man, monkey, whale, etc.); in others the reverse development occurs (*e.g.* the hedgehog and many other animals), in which the rhinencephalon forms a large part of the hemisphere and the pallium is relatively small.

Corpus Callosum, Septum Lucidum, and Fornix.

Corpus Callosum. — This is the great transverse commissure which passes between the two cerebral hemispheres. It is placed nearer the anterior than the posterior aspect of the brain, and it unites the inner surfaces of the hemispheres throughout very nearly a half of their antero-posterior length. The corpus callosum

is highly arched from before backwards, and presents a convex upper surface and a concave lower surface.

The *upper surface* of the corpus callosum forms the bottom of the great longitudinal fissure, and on each side of this it is covered by the callosal gyrus. Only in its posterior part is it touched by the falx cerebri; in front, this process of dura mater falls considerably short of it. The upper surface of the callosum is covered by a thin layer of gray matter continuous at the bottom of the callosal sulcus with the gray cortex on the surface of the hemisphere. In this there are embedded on either side of the mesial plane two delicate longitudinal bands of fibres, called respectively the stria longitudinalis medialis and lateralis. The **stria longitudinalis medialis** is the more strongly marked of the two, and it is separated from its neighbour of the opposite side by a faint mesial furrow. The **stria longitudinalis lateralis**

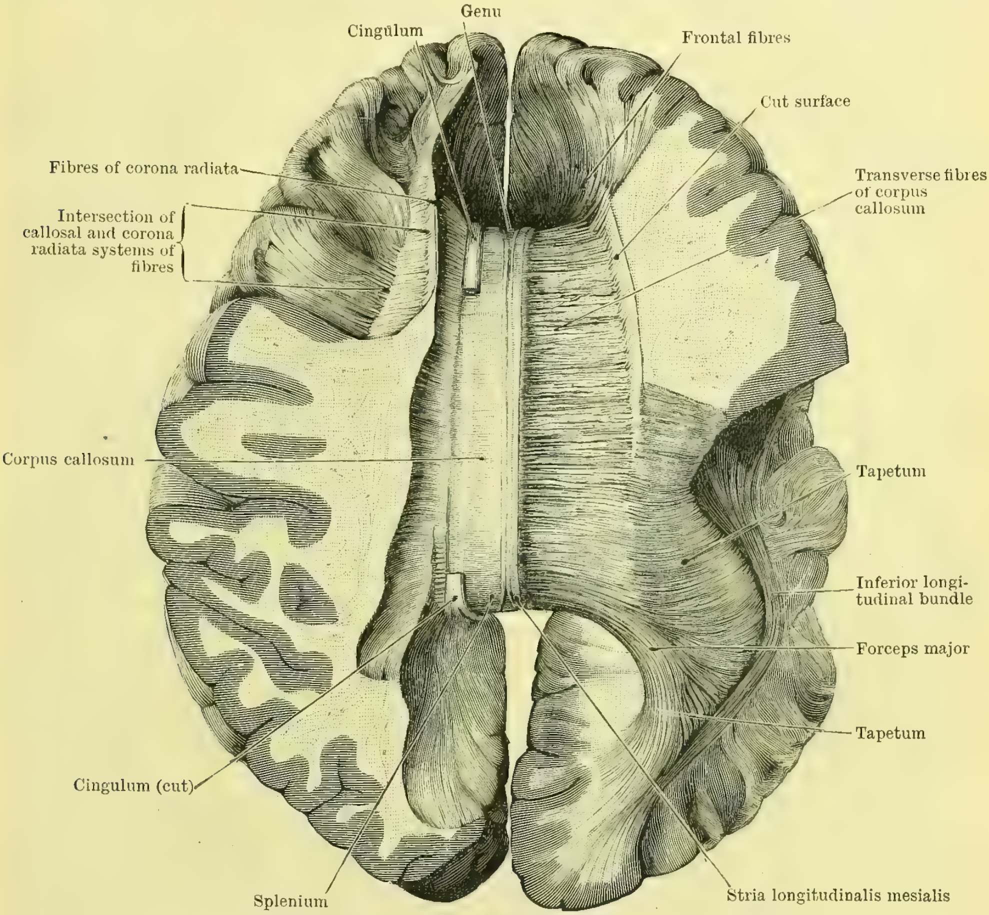


FIG. 392.—THE CORPUS CALLOSUM, exposed from above and the right half dissected, to show the course taken by its fibres.

is placed further out, under cover of the callosal gyrus. The thin coating of gray matter, with the two striæ, represent an aborted convolution, termed the **gyrus supracallosus.** So thin is the gray coating supplied by this gyrus that the transverse direction pursued by the callosal fibres proper can be easily perceived through it.

The two extremities of the corpus callosum are much thickened, whilst the intermediate part or **body** is considerably thinner. The massive *posterior end,* which is full and rounded, lies over the mesencephalon and extends backwards as far as the highest point of the cerebellum. It is called the **splenium**, and it consists of an upper and a lower part. The latter is bent forwards under the upper part, to the inferior surface of which it is closely applied. The *anterior end* of the corpus callosum is not quite so massive and is folded downwards and backwards on itself.

It is termed the **genu.** The recurved lower part of the genu is separated from the part of the corpus callosum, which lies above, by an interval. It rapidly thins as it passes backwards and receives the name of the **rostrum.** The fine terminal edge of the rostrum becomes connected with the lamina cinerea.

The gyrus supracallosus, with its contained medial and lateral longitudinal striæ, when traced backwards, is seen to turn round the splenium and become continuous with the gyrus dentatus. In front the mesial striæ, with the associated gray matter, are carried round the genu and then backwards on the under surface of the rostrum. As they turn round the genu they diverge from each other, and are termed the **gyri geniculi.** Reaching the hinder edge of the rostrum, each gyrus geniculus runs into the **gyrus subcallosus**—a narrow cortical strip on the mesial surface of the hemisphere, which runs downwards immediately in front of the lamina cinerea to the locus perforatus anticus. The gyrus subcallosus is often called the peduncle of the corpus callosum, and the fibres of the stria which it contains proceed backwards and outwards along the posterior limit of the anterior perforated spot to the anterior extremity of the temporal lobe. Dr. Elliot Smith has shown that these parts have an important morphological significance.

The *under surface* of the corpus callosum on either side of the mesial plane is for the most part free, and, lined by ependyma, it forms the roof of the anterior horn and body of the lateral ventricle. In the mesial plane, however, it is attached to subjacent parts, viz. to the septum lucidum in front and to the body of the fornix behind.

The transverse fibres of the corpus callosum, as they enter the white medullary centre of the cerebral hemisphere, radiate from each other so as to reach every part of the cerebral cortex. This radiation is termed the **radiatio corporis callosi** and the fibres which compose it intersect the fibres which form the corona radiata, or, in other words, the fibres which extend between the internal capsule and the cerebral cortex (Figs. 375, p. 505; and 403, p. 540). The more anterior of the fibres which compose the genu of the corpus callosum sweep forwards in a series of curves into the prefrontal region of the hemisphere. A large part of the splenium, forming a solid bundle termed the **forceps major,** bends suddenly and abruptly backwards into the occipital lobe (Fig. 398, p. 536). Fibres from the body and upper part of the splenium, curving round the lateral ventricle, form a very definite stratum, called the **tapetum.** This is a thin layer in the medullary centre of the hemisphere, which constitutes the immediate roof and outer wall of the posterior horn and the outer wall of the hinder part of the descending horn of the lateral ventricle. In coronal sections through the occipital and hinder temporal regions the tapetum stands out very distinctly (Figs. 391, p. 527; 397, p. 535; and 400, p. 538).

Fornix.—The fornix is an arched bilateral structure composed, for the most part, of longitudinally-directed fibres. In its intermediate part its two lateral halves are joined together in the mesial plane, and form what is called the body of the fornix; but in front and behind they are quite separate, and constitute the anterior and posterior pillars of the fornix.

The **body of the fornix** is triangular in form. In front, where it is continuous with the anterior pillars, it is narrow; whilst behind it broadens out, becomes flattened, and is finally prolonged into the posterior pillars. The upper surface of the body of the fornix is in contact with the under surface of the hinder part of the body of the corpus callosum, and posteriorly is adherent to it. In front of this, and in the mesial plane, it is attached to the septum lucidum. Beyond these attachments, on each side, the upper surface of the body of the fornix forms a part of the floor of the lateral ventricle and is clothed by the lining ependyma. It presents a sharp lateral edge or margin, from under which the choroid plexus projects into the cavity of the lateral ventricle and with which the epithelial layer which covers that plexus is continuous. The lower surface of the body of the fornix rests upon the velum interpositum, which separates it from the roof of the third ventricle and the upper surface of the optic thalami. It is not at all an uncommon occurrence to find the two lateral portions of the body of the fornix of unequal size (Fig. 396, p. 534).

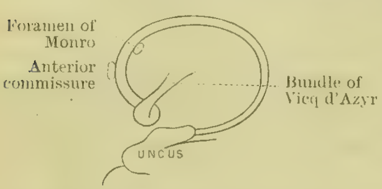


Fig. 393.—Diagrammatic Profile View of the Fornix.

The **anterior pillars of the fornix** (columnæ fornicis) are two rounded strands which emerge from the anterior part of the body of the fornix, and then diverge very slightly from each other as they curve downwards in front of the foramina of Monro. Sinking into the gray matter on the lateral wall of the third ventricle, each anterior pillar proceeds downwards to the base of the brain, and in the interpeduncular space protrudes, to take part in the formation of the corpus mammillare. When the corpus mammillare is dissected it appears to be largely formed of a twisted loop of the anterior pillar of the fornix, in which the pillar bends upon itself, and is then continued upwards and backwards into the optic thalamus. This appearance, however, is misleading. The fibres of the anterior pillar end in the gray nucleus of the corpus mammillare, and the strand which passes from this to the thalamus is the **bundle of Vicq d'Azyr** (p. 507).

The **posterior pillars of the fornix** (crura fornicis) are flattened bands which diverge widely from each other. At first they are adherent to the under surface of the corpus callosum, but soon they sweep downwards round the posterior ends of the optic thalami and enter the descending horns of the lateral ventricles. Here each pillar comes into relation with the corresponding hippocampus major, and a portion of its fibres are spread out on the surface of this prominence, forming the **alveus**, whilst the remainder constitute the **fimbria** or **tænia fornicis**—a narrow but very distinct band of white matter, which is attached by its outer margin along the inner border of the hippocampus major and ends in front by joining the uncus (p. 527).

A certain number of transverse fibres enter into the formation of the fornix. The diverging posterior pillars enclose between them a small triangular space on the under surface of the hinder part of the corpus callosum. This area is crossed by transverse fibres, which form a thin lamina called the **psalterium** or **lyra**. Sometimes the psalterium is not completely fused to the under surface of the corpus callosum, and in these cases a narrow space is left between them, which receives the name of **Verga's ventricle**.

The fornix is intimately connected with the olfactory apparatus. Its fibres, for the most part, arise from the pyramidal cells in the cornu ammonis or hippocampus major and ascend in the fimbria and posterior pillar. In the region of the psalterium numerous fibres cross the mesial plane, enter the opposite posterior pillar, and in it proceed to the opposite cornu ammonis. These fibres constitute a commissure between the two cornua ammonis. The remainder of the fibres proceed forwards in the body of the fornix, and by means of the anterior pillar the majority of the fibres are carried downwards, behind the anterior commissure, to the corpus mammillare. Some, however, curve backwards into the stria medullaris (p. 506); whilst others, forming the **olfactory bundle of the cornu ammonis**, pass in front of the anterior commissure and enter the septum lucidum, through which they reach the subcallosal gyrus and the locus perforatus anticus. Finally, this bundle divides into two parts, of which one joins the inner root of the olfactory tract, whilst the other goes to the uncus.

The greater number of the longitudinal fibres of the fornix must, therefore, be regarded as establishing a connexion between the cornu ammonis and the optic thalamus. The nucleus of the corpus mammillare is an internode interposed in the path of this connecting tract. The bundle of Vicq d'Azyr, formed by the relay of fibres which takes origin in this internode, forms the second link in the chain.

The striæ longitudinales on the upper surface of the corpus callosum are to be regarded, from a morphological point of view, as forming an outlying part of the fornix system.

Septum Lucidum (septum pellucidum).—This is a thin vertical partition which intervenes between the anterior cornua and foreparts of the bodies of the two lateral ventricles. It is triangular in shape, and posteriorly it is prolonged backwards for a variable distance between the body of the corpus callosum and the fornix, to both of which it is attached by its upper and lower edges. In front it occupies the gap behind the genu of the corpus callosum, whilst below, in the narrow interval between the posterior edge of the rostrum of the corpus callosum and the fornix, it is prolonged downwards towards the base of the brain in the gyrus subcallosus. The septum lucidum is composed of two thin laminæ in apposition with each other in the mesial plane (Fig. 396, p. 534).

Fifth Ventricle (cavum septi pellucidi).—This is the name which is applied to the mesial cleft between the two laminæ of the septum lucidum. It varies greatly in size in different brains and contains a little fluid. It is completely isolated and

presents no communication with the other ventricles of the brain. Indeed, the term "ventricle," as applied to it, is quite inappropriate, seeing that at no period in the development of the brain has it any connexion with the general ventricular system. It is usually stated that it represents a portion of the great longitudinal fissure, which has become cut off and walled round about by the growing commissures of the hemispheres, but it is doubtful if this is the case (*see* p. 555).

Lateral Ventricle.

The cavity in the interior of the cerebral hemisphere is called the lateral ventricle. It is lined throughout by ependyma continuous with the ependymal lining of the third ventricle. In many places the walls of the cavity are in apposition, whilst in other localities spaces of varying capacity, and containing cerebro-spinal fluid, are left between the bounding walls.

The **lateral ventricle** (ventriculus lateralis) communicates with the third ventricle of the brain by means of a small foramen, just large enough to admit a crow-quill, which is termed the **foramen of Monro**. This aperture is placed in front of the fore end of the optic thalamus and behind the anterior pillar of the fornix.

The highly-irregular shape of the lateral ventricle can be best understood by the study of a cast of its interior (Figs. 394; and 379, p. 509). It is usual to describe it as being composed of a body and three horns, viz. an anterior, a posterior, and a descending horn. The **anterior horn** is that part of the cavity which lies in front of the foramen of Monro. The **body** is the portion of the ventricle which extends from the foramen of Monro to the splenium of the corpus callosum. At this point the posterior and descending horns diverge from the hinder part of the body. The **posterior horn** curves backwards and inwards into the occipital lobe. It is very variable in its length and capacity. The **descending horn** proceeds with a bold sweep round the hinder end of the optic thalamus, and then tunnels in a forward and inward direction through the temporal lobe towards the temporal pole. The early fœtal lateral ventricle is very capacious and presents an arched or semilunar form. It is composed of parts which correspond to the anterior horn, the body, and the descending horn, and there is little or no demarcation between them. The posterior horn is a later production. It comes into existence with the occipital lobe and is produced as a diverticulum or elongated pouch, which grows backwards from the upper and hinder part (*i.e.* the convexity) of the primitive cavity.

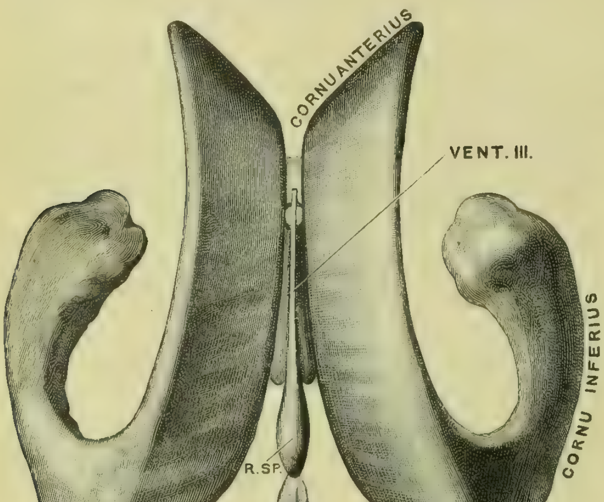


Fig. 394.—Drawing taken from a Cast of the Ventricular System of the Brain, as seen from above (after Retzius).
Vent. III. Third ventricle. Vent. IV. Fourth ventricle.
R.SP. Recessus suprapinealis.

Anterior Horn of the Lateral Ventricle (cornu anterius).—The anterior horn forms the foremost part of the cavity, and extends in a forward and outward direction in the frontal lobe. When seen in coronal section it presents a triangular

outline, the floor sloping upwards and outwards to meet the roof at an acute angle. It is bounded *in front* by the posterior surface of the genu of the corpus callosum; the *roof* is also formed by the corpus callosum. The *inner wall*, which is vertical, is formed by the septum lucidum; whilst the sloping *floor* presents a marked elevation or bulging, viz. the smooth, rounded, and prominent extremity of the pear-shaped caudate nucleus.

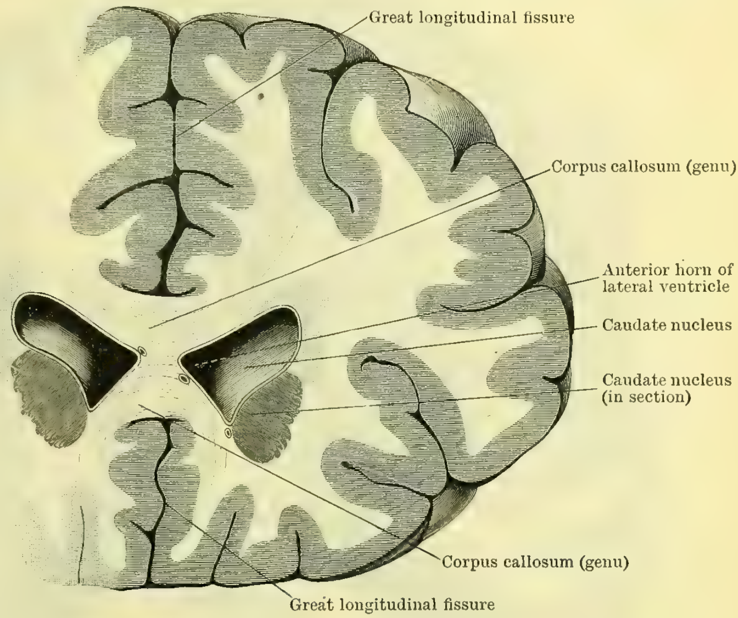


FIG. 395.—CORONAL SECTION THROUGH THE FRONTAL LOBES AND THE ANTERIOR HORNS OF THE LATERAL VENTRICLES.

Body of the Lateral Ventricle (pars centralis).—The body of the cavity is likewise *roofed* by the corpus callosum. On the *inner* or *mesial side* it is bounded by the attachment of the fornix to the under surface of the corpus callosum and by the hinder part of the septum lucidum. On the *outer side* it is closed, as in the case of the anterior horn, by the meeting of the floor and the roof of the cavity. On the *floor* a number of important objects may be recognised. From without inwards these are met in the following order: (1) the caudate nucleus; (2) a groove which extends obliquely from before backwards and outwards between the caudate nucleus and the optic thalamus, and in which are placed the vein of the corpus striatum and a white band called the tænia semicircularis; (3) a portion of the upper surface of the optic thalamus; (4) the choroid plexus; (5) the thin sharp lateral edge of the fornix.

The **caudate nucleus** narrows rapidly as it proceeds backwards on the outer part of the floor of the body of the lateral ventricle. The **vein of the corpus striatum** is covered over by ependyma. It joins the vein of Galen close to the foramen of Monro. The connexions of the **tænia semicircularis** will be dealt with later. The portion of the upper surface of the **optic thalamus** which appears in the floor of the ventricle is in great part hidden by the choroid plexus, which lies upon it. The **choroid plexus** is a rich vascular fringe which appears from under cover of the sharp lateral edge of the fornix. In front it is continuous, behind the foramen of Monro, with the corresponding choroid plexus of the opposite side, whilst behind, it is carried into the descending horn of the ventricle. Although the choroid plexus has all the appearance of lying free within the ventricle, it must be borne in mind that it is invested by an epithelial layer which represents a portion of the hemisphere wall and excludes it from the cavity. This thin layer is continuous on the one hand with the sharp edge of the fornix, and on the other it is attached to the upper surface of the optic thalamus.

Posterior Horn of the Lateral Ventricle (cornu posterius).—The posterior horn is an elongated diverticulum carried backwards into the occipital lobe from the hinder end of the body of the ventricle. It tapers to a point and describes a gentle curve, the convexity of which is directed outwards. The *roof* and *outer wall* of this portion of the ventricular cavity are formed by the tapetum of the corpus callosum. In coronal sections through the occipital lobe this is seen as a thin but distinct layer of white fibres, which lies immediately outside the ependyma and to the inner

side of a much larger strand of fibres in the medullary substance of the occipital lobe, viz. the optic radiation.

On the *inner wall* two elongated curved elevations may be observed. The

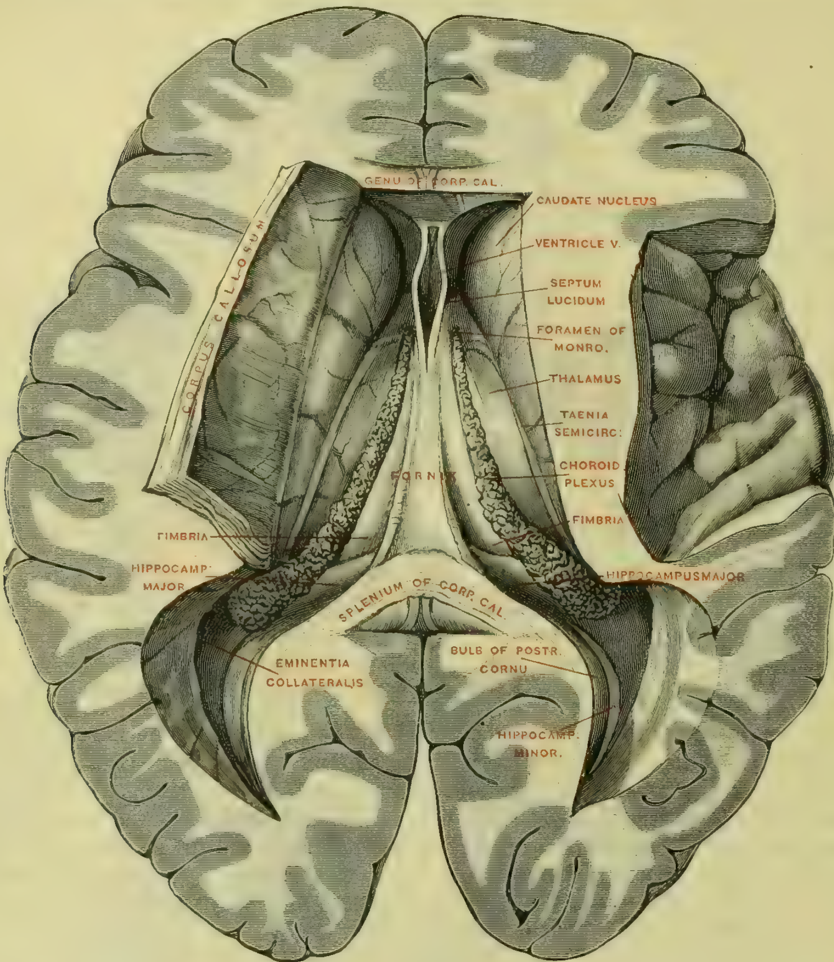


FIG. 396.—DISSECTION, to show the fornix and lateral ventricles ; the body of the corpus callosum has been turned over to the left.

uppermost of these is termed the **bulb of the cornu** (bulbus cornu posterioris), and is produced by the fibres of the forceps major of the corpus callosum as they curve abruptly backwards from the lower part of the splenium of the corpus callosum into the occipital lobe. Below this is the elevation known as the **calcar avis**. It varies greatly in size in different brains and is caused by an infolding of the ventricular wall in correspondence with the anterior calcarine fissure on the exterior of the hemisphere.

Descending Horn of the Lateral Ventricle (cornu inferius).—The descending horn is the continuation of the cavity into the temporal lobe. At first directed backwards and outwards, the descending horn suddenly sinks downwards behind the optic thalamus into the temporal lobe, in the centre of which it takes a curved course forwards and inwards to a point about an inch behind the extremity of the temporal pole.

In the angle between the diverging posterior and descending horns the cavity of the ventricle presents an expansion of a somewhat triangular shape. To this, the name of **trigonum ventriculi** is sometimes given.

The *roof* of the descending horn is formed for the most part by the tapetum of the corpus callosum. At the extremity of the horn the roof presents a bulging into the cavity. This is the **amygdaloid tubercle**, and it is produced by a super-

jacent collection of gray matter termed the amygdaloid nucleus. The **tænia semicircularis** and the attenuated **tail of the caudate nucleus** are both prolonged into the descending horn and are carried forwards, in its roof, to the amygdaloid nucleus.

On *the floor* of the descending horn the following structures are seen: (1)

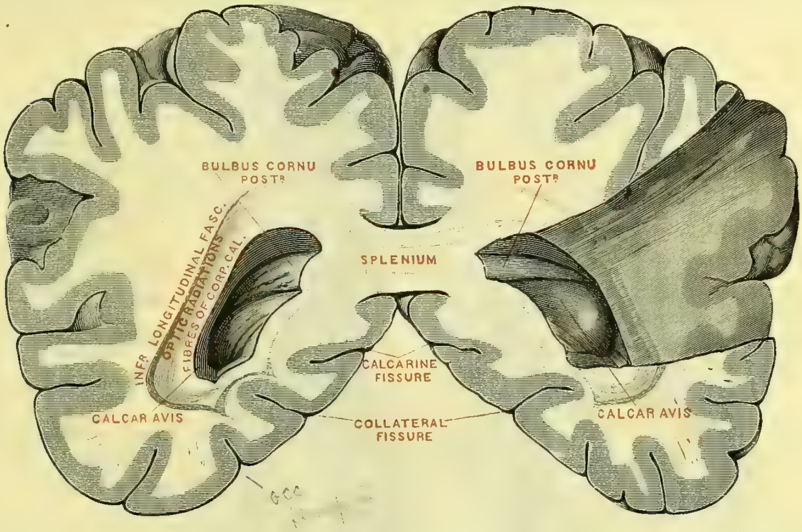


FIG. 397.—CORONAL SECTION THROUGH THE POSTERIOR HORNS OF THE LATERAL VENTRICLES.

hippocampus major, or the cornu ammonis; (2) the choroid plexus; (3) the fimbria; and (4) the eminentia collateralis.

The **hippocampus major** (hippocampus) is for the most part covered by the choroid plexus. It is a prominent elevation on the floor of the descending horn of the lateral ventricle and is strongly curved, in conformity with the course taken by the horn in which it lies. It therefore presents an internal concave margin and an external convex border. Narrow behind, it enlarges as it is traced forwards, and it ends below the amygdaloid tubercle in a thickened extremity, which presents some faint grooves or notches on its surface. In consequence of this, the anterior end of the hippocampus major receives the name of the **pes hippocampi.** The hippocampus major is the internal elevation which corresponds to the dentate fissure on the exterior of the hemisphere (Fig. 399).

The **fimbria** (fimbria hippocampi) is the narrow band of white matter which is attached by its outer margin along the inner concave border of the hippocampus major. The white matter composing it is continuous with the thin white layer (the alveus) which is spread over the surface of the hippocampus major, and it presents two free surfaces and a sharp free inner border. The fimbria has already been examined in connexion with the hippocampal fissure and the gyrus dentatus (p. 527), and the relations which it presents to the fornix and the uncus have been pointed out.

When the pia mater in the region of the hippocampal fissure is removed from the surface of the brain, the choroid plexus in the interior of the descending horn of the lateral ventricle is usually withdrawn with it, and a fissure appears between the fimbria and the roof of the ventricular horn. This is the **choroid fissure.** It appears at a very early date in the development of the cerebral hemisphere, and takes an arcuate course upwards and forwards round the hinder end of the optic thalamus. In the region of the body of the lateral ventricle it extends as far forwards as the foramen of Monro, and is formed by the involution of an epithelial part of the wall of the ventricle over the choroid plexus (p. 533). In the region of the descending horn, when the choroid plexus with the involuted epithelial layer which covers it is withdrawn, the choroid fissure is converted into an artificial gap which leads directly into this part of the ventricular cavity.

The **choroid plexus** is a convoluted system of blood-vessels in connexion with a fold of pia mater, which is prolonged into the descending horn of the lateral

ventricle. It lies on the surface of the hippocampus major and is continuous behind the posterior part of the optic thalamus, with the choroid plexus in the body of the lateral ventricle. But it must not be supposed that the choroid plexus lies free in the ventricular cavity. It is clothed in the most intimate manner by an epithelial layer, which represents the inner or mesial wall of the descending horn

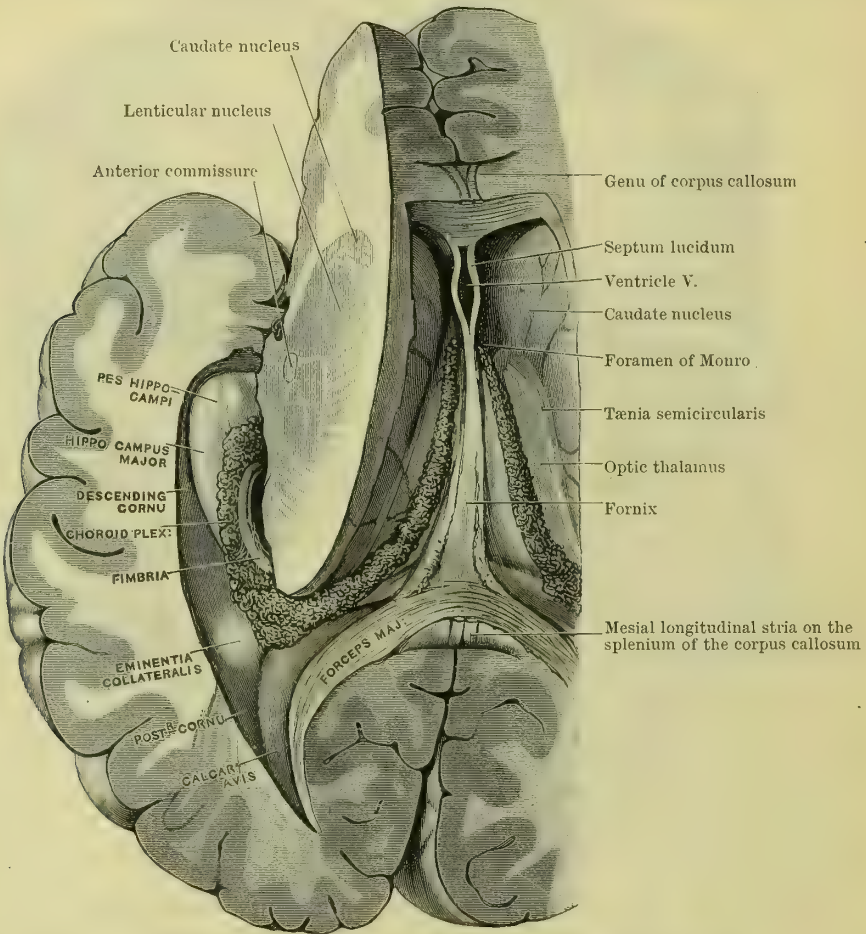


FIG. 398.—DISSECTION, to show the fornix and the posterior and descending cornua of the lateral ventricle of the left side.

pushed into the cavity by the choroid plexus. The ventricle, therefore, only opens on the surface through the choroid fissure when this thin epithelial layer is torn away by the withdrawal of the choroid plexus. From the above, it will be understood that the arcuate choroid fissure, throughout its whole length (viz. from the foramen of Monro to the extremity of the descending horn of the lateral ventricle), is formed by the involution of a portion of the wall of the hemisphere which remains epithelial. In the body of the ventricle this layer is attached, on the one hand, to the sharp lateral margin of the fornix, and on the other to the upper surface of the optic thalamus; in the descending horn it is attached, in like manner, to the edge of the fimbria or posterior pillar of the fornix, whilst above it joins the roof of this portion of the ventricle along the line of the tænia semicircularis.

The **eminentia collateralis** shows very great differences in its degree of development, and it may present two distinct forms, which may be distinguished from each other as the eminentia collateralis posterior and the eminentia collateralis anterior.

The *posterior collateral eminence* is a smooth elevation in the floor of the trigonum ventriculi, in the interval which is left between the calcar avis and the hippocampus major as they diverge from each other. In the fœtal brain this is

always a very strongly-marked elevation, which corresponds with the mid-collateral fissure, but in the course of growth it is apt to lose much of its prominence

The *anterior collateral eminence* is only occasionally present. It appears as an elongated elevation of varying length and prominence, on the floor of the descending horn of the lateral ventricle, on the outer side of the hippocampus major. It is formed by the anterior portion of the fœtal collateral sulcus, when this develops as a complete fissure.

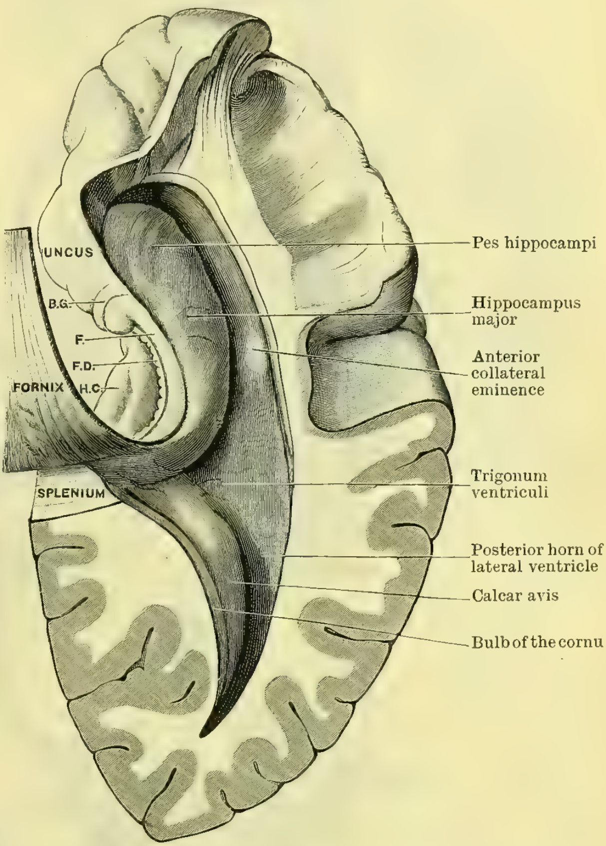


FIG. 399.—DISSECTION, to show the posterior and descending cornua of the lateral ventricle.

B.G. Giacomini's band. F. Fimbria. F.D. Gyrus dentatus. H.C. Hippocampal convolution.

BASAL GANGLIA OF THE CEREBRAL HEMISPHERE.

Under this heading are included certain masses of gray matter more or less completely embedded in the white medullary substance of the hemisphere, and which are developed in its wall. They compose the caudate and lenticular nuclei, which together form the corpus striatum, the claustrum, and the amygdaloid nucleus.

The **caudate nucleus** bulges into the lateral ventricle. It is a pyriform, highly-arched mass of gray matter, which presents a thick, swollen head, or anterior extremity, and a long, attenuated tail. The head projects into the anterior horn of the lateral ventricle, whilst its narrower part is prolonged outwards and backwards in the floor of the body of the ventricle, where it is separated from the optic thalamus by the tænia semicircularis. Finally, its tail curves downwards with a bold sweep and enters the descending horn of the lateral ventricle. In the roof of this it is prolonged forwards to the amygdaloid nucleus, the lower part of which it joins. The caudate nucleus thus presents a free ventricular surface, covered with ependyma, and a deep surface embedded in the white substance of the cerebral hemisphere, and for the most part related to the internal capsule.

Owing to its arched form it follows that, in horizontal sections through the cerebral hemisphere below a particular level, it is cut at two points, and both the head and the tail appear on the field of the section (Fig. 400). In coronal sections behind the amygdaloid nucleus, it is also divided at two places (Fig. 375, p. 505).

The anterior extremity of the head of the caudate nucleus coincides very nearly with that of the anterior horn of the lateral ventricle. In the region of the locus perforatus anticus, the head of the caudate nucleus gains the surface and its gray matter becomes continuous with that of the cerebral cortex.

The **lenticular nucleus** lies on the outer side of the caudate nucleus and optic thalamus, and is for the most part embedded within the white medullary substance of the cerebral hemisphere. It does not extend either so far forwards or so far backwards as the caudate nucleus. Indeed, it presents a very close correspondence in point of extent with the insula or island of Reil on the surface. When seen in

horizontal section, it presents a shape similar to that of a biconvex lens. Its inner surface bulges more than the outer surface, and its point of highest convexity is placed opposite the tænia semicircularis or the interval between the caudate nucleus and the optic thalamus. In coronal section the appearance presented by the lenticular nucleus differs very much in different planes of section. Fig. 401 represents a section through its anterior portion. Here it is semilunar or crescentic in outline and is directly continuous below with the head of the caudate nucleus; above, also, it is intimately connected with the caudate nucleus by bands of gray matter, which pass between the two nuclei and break up the white matter of the forepart of the intervening internal capsule. It is due to the ribbed or barred appearance, which is presented by such a section as this, that the term **corpus striatum** is applied to the two nuclei. In the region of the locus perforatus anticus both nuclei reach the surface and become continuous with the cortex.

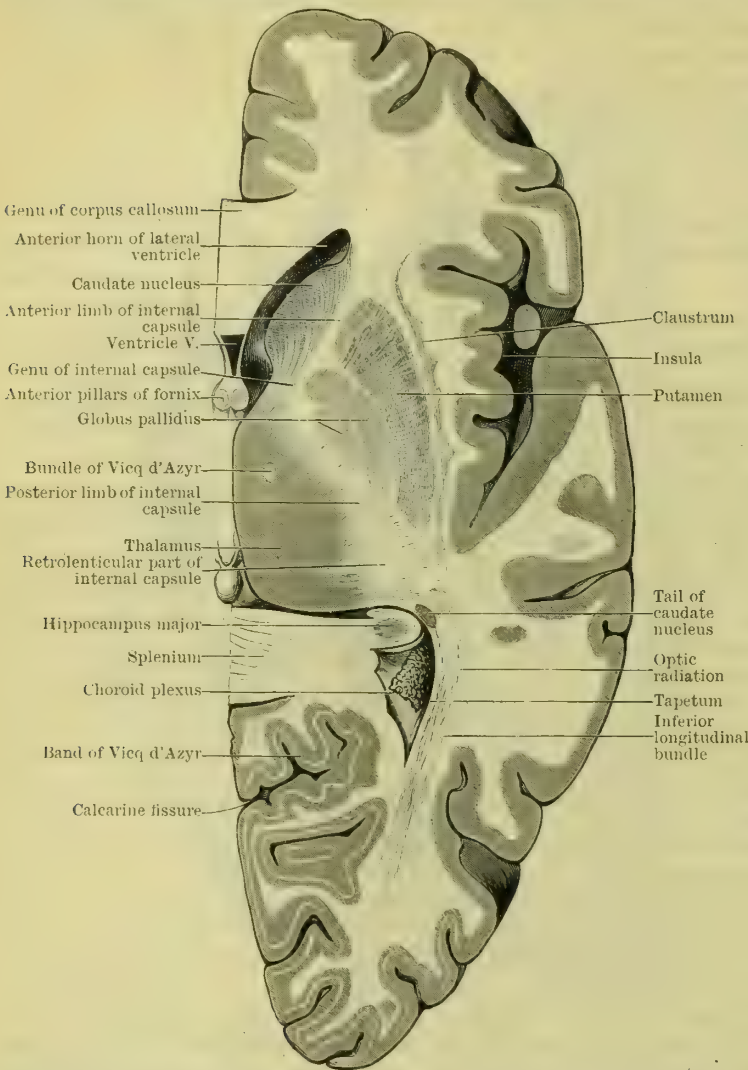


Fig. 400.—Horizontal Section through the Right Cerebral Hemisphere at the Level of the Widest Part of the Lenticular Nucleus.

When a section is made in a plane further back (*e.g.* immediately posterior to the anterior commissure, as in Fig. 402) the divided lenticular nucleus assumes an altogether different shape, and is seen to be completely cut off from the caudate nucleus by the internal capsule. It is now triangular or wedge-shaped. Its *base* is turned towards the island of Reil and is in direct relation to a thin lamina of white matter, termed the external capsule. Its *internal surface* is oblique and is applied to the internal capsule, whilst its *inferior surface* is horizontal and is directed downwards towards the base of the brain. But, further, two white laminæ, the **external** and **internal medullary laminæ**, are now evident, which traverse its substance in a vertical direction and divide it into three zones. The outer, basal, and larger zone is termed the **putamen**; the two inner portions together constitute the **globus pallidus**.

The **putamen** forms much the largest part of the lenticular nucleus. It is

darker in colour than the globus pallidus, and in this respect resembles the caudate nucleus. It is traversed by fine radiating bundles of fibres, which enter it from the external medullary lamina. Both in point of structure and in mode of development it is closely associated with the caudate nucleus, and it is the only part of the lenticular nucleus which is connected by intervening bands of gray matter with the caudate nucleus. The antero-posterior length, as well as the vertical depth of the putamen, is much greater than in the case of the globus pallidus; consequently, in both coronal and horizontal sections through the cerebrum it is encountered before the plane of the globus pallidus is reached.

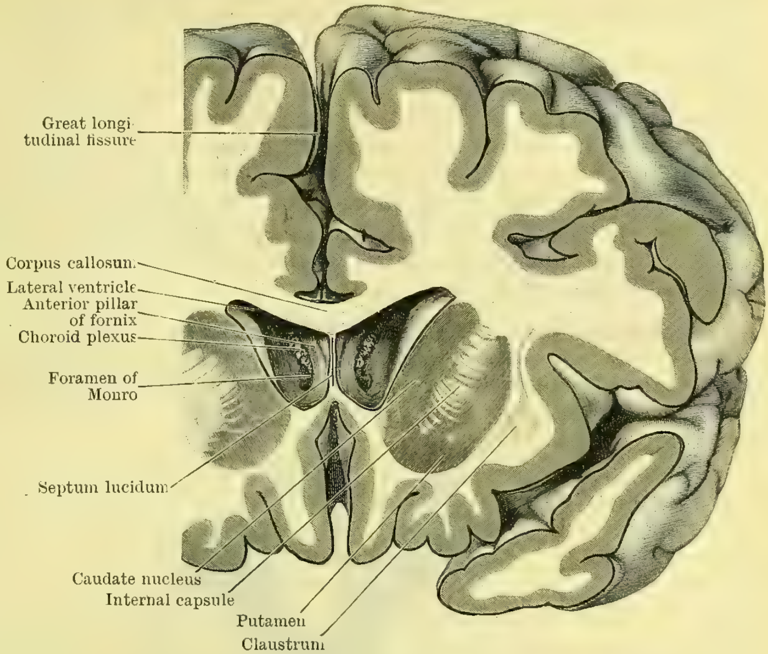


FIG. 401.—CORONAL SECTION THROUGH THE CEREBRAL HEMISPHERES so as to cut through the anterior part (putamen) of the lenticular nucleus in front of the globus pallidus.

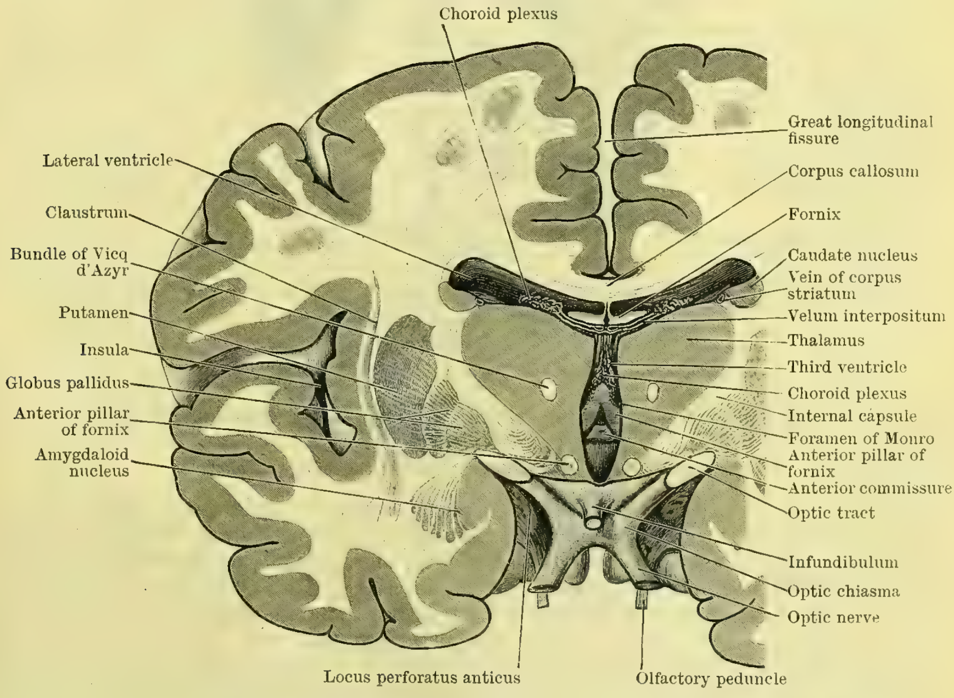


FIG. 402.—CORONAL SECTION THROUGH THE CEREBRUM, so as to cut through the three divisions of the lenticular nucleus; posterior surface of the section depicted.

The external capsule is loosely connected with the outer surface of the putamen, and it can be readily stripped off. This accounts for the tendency, exhibited in hæmorrhages in this locality, for the effused blood to spread out in the interval between these structures.

The **globus pallidus** is composed of the two smaller and inner zones of the lenticular nucleus. They present a faint yellowish tint, and are paler and more abundantly traversed by fibres than the putamen. The zone next the putamen (*i.e.* the intermediate zone) is much larger than the innermost subdivision. It extends forwards to a point a little in front of the plane of the anterior commissure. When the lenticular nucleus is cut in a coronal direction, and in its widest part, the innermost zone shows an indication of a separation into two parts, so that here the globus pallidus appears to consist of three subdivisions. The morphology of the globus pallidus is by no means clear.

Connexions of the Corpus Striatum.—(1) Numerous fibres from the optic thalamus pass into the anterior limb of the internal capsule and enter both the caudate and the lenticular nuclei. These may be termed the **thalamo-striate fibres.** (2) Edinger

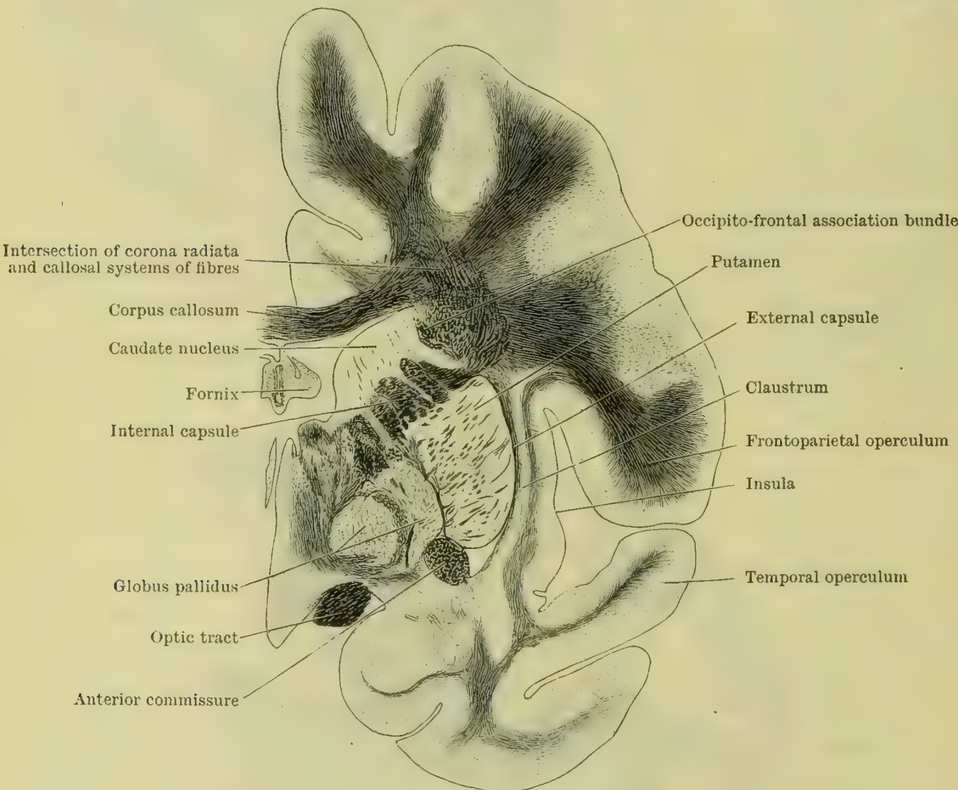


FIG. 403.—CORONAL SECTION THROUGH THE LEFT SIDE OF THE CEREBRUM OF AN ORANG (Weigert-Pal specimen).

The section passes through the middle of the lenticular nucleus.

describes a connexion between the caudate nucleus and the substantia nigra. The connecting fibres pass through the subthalamic region and constitute a tract in the mesencephalon, in close apposition with the substantia nigra, called the **stratum intermedium.** (3) The **ansa lenticularis** has previously been described. It is composed of fibres which come from the inferior part of the fore portion of the thalamus and curve outwards under the lenticular nucleus. They stream upwards into this and through its medullary laminæ. Many of them apparently proceed onwards to the cerebral cortex. (4) Fibres from the posterior limb of the internal capsule (thalamic fibres chiefly) enter the lenticular nucleus and stream through it, and its medullary laminæ, on their way to the cerebral cortex.

Claustrum.—This is a thin plate of gray substance embedded in the white matter, which intervenes between the lenticular nucleus and the gray cortex of the

insula or island of Reil. Followed in an upward direction, it becomes gradually thinner and ultimately disappears. As it is traced downwards, however, it thickens considerably, and at the base of the brain it comes to the surface at the anterior perforated spot and becomes continuous with the gray matter of the cortex. Its extent corresponds very closely with the area occupied by the insula, and its surface towards this portion of the cerebral cortex shows ridges and depressions corresponding to the insular gyri and sulci.

Amygdaloid Nucleus.—In the forepart of the temporal lobe, in front of, and to some extent above the extremity of the descending horn of the lateral ventricle, there is a round mass of gray matter, called the amygdaloid nucleus. The tail of the caudate nucleus joins its lower part, whilst above it is carried up into the putamen. In front it is continuous with the gray cortex of the cerebrum.

Tænia Semicircularis.—This is a band of fibres which, for the most part, arise in the amygdaloid nucleus. From this it runs backwards in the roof of the descending horn of the lateral ventricle, and then arches upwards and forwards, so as to gain the floor of the body of the lateral ventricle. In both situations it lies close to the inner side of the nucleus caudatus, and finally, at the foramen of Monro, it bends downwards towards the anterior commissure. Some of its fibres pass in front and others behind the commissure, and ultimately they end in the locus perforatus anticus (Kölliker).

Internal Capsule.—This term is applied to the broad band of white matter which intervenes between the lenticular nucleus, on the outside, and the optic thalamus, tænia semicircularis, and caudate nucleus on the inner side. It presents many different appearances, according to the plane in which the brain is cut. In the region of the mesencephalon, a coronal section through the brain shows that in great part the internal capsule is directly continuous with the crusta of the crus cerebri (Fig. 375, p. 505). In horizontal section the internal capsule is observed to be bent upon itself opposite the tænia semicircularis, or the interval between the caudate nucleus and the thalamus. This bend, which points inwards, is called the **genu**. About one-third of the internal capsule lies in front of the genu, and is termed the anterior limb; the remaining two-thirds, which lie behind the genu, constitute the posterior limb.

The **anterior limb of the internal capsule** intervenes between the lenticular nucleus and the caudate nucleus. In its lower and forepart it is much broken up by the connecting bands of gray matter which pass between the forepart of the putamen and the lenticular nucleus.

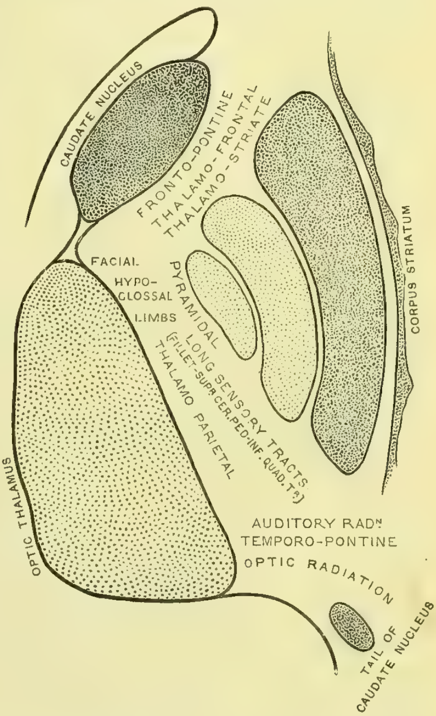


Fig. 404.—Diagrammatic Representation of the Internal Capsule (as seen in horizontal section).

The anterior limb of the internal capsule is, for the most part, composed of corticipetal fibres belonging to the thalamic radiation. It likewise contains a distinct corticifugal tract. The corticipetal fibres are of two kinds, viz.: thalamo-frontal and thalamo-striate. The former, which arise in the optic thalamus, go through the anterior limb of the internal capsule to reach the cortex of the frontal lobe. The thalamo-striate fibres likewise arise in the thalamus and enter the anterior limb, to reach the caudate and lenticular nuclei.

The corticifugal fibres form a tract which has already been referred to in connexion with the mesencephalon. It is the **fronto-pontine tract**, which arises in the cortex of the prefrontal region, traverses the anterior limb of the internal capsule, forms the inner fifth of the crusta of the crus cerebri, and finally ends in the nucleus pontis.

The **posterior limb of the internal capsule** is placed between the optic thalamus and the lenticular nucleus, and it extends backwards for a short distance beyond the hinder end of the putamen on the outer side of the posterior part of the thalamus and of the tail of the caudate nucleus. The posterior limb, therefore, is spoken of as consisting of a lenticular and a retrolenticular part.

The **lenticular part** of the posterior limb is composed of both corticipetal and corticifugal fibres. The **corticipetal fibres** enter the internal capsule from the outer aspect of the optic thalamus, and are composed of thalamic fibres which arise within the thalamus, and also, in all probability, certain long tracts (such as portion of the mesial fillet and portion of the superior cerebellar peduncle), which are said to be carried up through the thalamus into the internal capsule.

The **corticifugal fibres** form a well-defined tract, which occupies the anterior half of the lenticular part of the internal capsule. This is the great **motor** or **pyramidal tract** descending from the Rolandic area of the cortex. The fibres, which go to the nucleus of the facial nerve, lie close to the genu, and behind these are the fibres which go to the hypoglossal nucleus; still further back are pyramidal fibres, which enter the spinal cord and end around the motor cells of the anterior horn of gray matter. This pyramidal tract has been observed occupying the middle part of the crusta of the crus cerebri, into which it passes directly from the internal capsule. It is doubtful if there are any other corticifugal fibres in the lenticular part of the posterior limb of the internal capsule. Some observers, however, consider that with the pyramidal fibres there are cortico-pontine fibres from the Rolandic area—fibres which end below in the nucleus pontis (van Gehuchten).

The **retrolenticular part** of the posterior limb contains: (1) the fibres of the optic radiation as they pass to establish their connexions with the thalamus, superior quadrigeminal body, and corpus geniculatum externum; (2) the fibres of the auditory radiation, or those which connect the auditory cortical field in the temporal lobe with the corpus geniculatum internum (Fig. 357, p. 480); (3) the temporo-pontine tract, which is composed of fibres which take origin in the two upper convolutions of the temporal lobe and pass through this section of the internal capsule to reach the outer part of the crusta of the crus cerebri. Through this they reach the ventral part of the pons, in the gray matter of which they end.

When the fibres of the internal capsule are traced upwards they are found to spread out widely from each other in a radiating or fan-shaped manner, so as to reach the various convolutions of the cerebral hemisphere. This arrangement is termed the **corona radiata**. The callosal system of fibres, as they proceed into the hemisphere, also radiate, and they intersect the fibres of the corona radiata (Fig. 403, p. 540).

External Capsule.—The thin lamina of white matter between the outer aspect of the putamen and the claustrum is called the external capsule. This joins with the internal capsule in front of and behind the putamen, and in this manner the lenticular nucleus is encapsulated by white matter.

Intimate Structure of the Cerebral Hemisphere.

The cerebral hemisphere is composed of an external coating of gray matter, termed the **cortex**, spread over an internal mass of white matter, which is called the **medullary centre**. The cortex is of peculiar interest, seeing that there is good reason for believing that in it the higher functions of the brain, or those which may be classed under the general designation of the intellectual functions, take place. It is within the same layer of gray matter that the influence of those external impressions, which gain access to the cerebro-spinal axis through the senses, finally take shape as consciousness; and in it also are placed the centres which carry on the psycho-motor functions. The white medullary centre is composed of nerve-fibres which constitute the paths along which the influence of impressions is carried to and from the cortex, and from one part of the cortex to another.

The Cerebral Cortex.

The gray cortex is spread over the entire surface of the cerebral hemisphere, but it does not form a layer of equal thickness in all localities. At the summit of a

convolution it is always thicker than at the bottom of a furrow. The maximum thickness of cortex (about 6 mm.) is attained in the upper parts of the two central convolutions, whilst the minimum (about 2·5 mm.) may be observed in the region of the occipital pole. The amount of gray cortex differs considerably in different individuals, and appreciably diminishes in old age. It is also stated, but upon very imperfect evidence, that it is relatively more abundant in the male than in the female.

In structure, likewise, marked differences may be noted in the gray cortex of different regions. In certain localities this is quite apparent to the naked eye when sections are made through it, but the relation which this bears to the functions displayed by these different regions is, to a great extent, unknown. Further, there are no sharp transitions in structure. One form of cortex passes gradually and insensibly into the variety of cortex which is distinctive of an adjoining region, and throughout the whole mass a general ground type may be recognised. It is only to those general structural features which more or less characterise the entire cortical layer that we shall be able to refer.

When sections are made through the fresh brain, and the cut surface is closely inspected, it will usually be apparent that the cortex is indistinctly stratified. On the outside there is a thin, whitish layer, and beneath this the gray matter presents two strata of very nearly equal thickness, viz. : a middle, gray-coloured stratum and an inner, yellowish-red stratum. Between the two latter layers a narrow white band is, in many places, visible. This is termed the **outer band of Baillarger.** When the layers indicated above are present, four strata superimposed on each other are recognised; but in certain regions, as, for instance, in the anterior central convolution, a second white streak traverses the deep or inner gray layer and divides it into two. This is termed the **inner white band of Baillarger**, and, when it is present, the gray cortex becomes divided obscurely into six alternating white and gray layers.

The outer band of Baillarger is strongly marked in the region of the calcarine fissure and gives a characteristic appearance to this portion of the cortex. In this locality it receives the name of the **band of Vicq d'Azyr** (Fig. 400, p. 538).

To obtain a full understanding of the minute structure of the cerebral cortex many different methods must be employed, and it is only by combining the several separate pictures which are thus afforded that the end in view is, in some measure, reached.

The stratification indicated above has little bearing upon the more essential points of the intimate structure of the cortex. The three white layers are brought about by an aggregation of fibres running in a tangential direction, or, in other words, in a direction parallel to the surface of the convolution.

Nerve-cells.—According to the arrangement and the characters presented by the nerve-cells which are met with at different depths, it is now usual to recognise four layers in the cortex. These are: (1) the stratum zonale; (2) the layer of small pyramidal cells; (3) the layer of large pyramidal cells; and (4) the layer of polymorphic cells.

As the pyramidal cells are specially characteristic of the cerebral cortex, we shall describe the two layers which contain them first. The difference between these two layers largely depends upon the difference in the size of the constituent cells. Taken together, the second and third layers constitute the chief part of the cortex; they merge insensibly into each other, and, in the parietal and frontal lobes, the layer of large pyramidal cells is the thickest of all the layers. In both of these strata the pyramidal cells present the same form, and apparently also similar connexions.

A **pyramidal cell** has a triangular outline. Its apex is directed towards the surface of the convolution and is drawn out into a long, tapering, apical, dendritic process; its base is turned towards the medullary centre of the gyrus, and from this (usually from the centre) a slender axon proceeds. Numerous lateral dendrites are given off from both sides of the cell-body, and particularly from the two basal corners. The apical dendrite varies in length, according to the depth at which the cell is placed. In every case it passes straight towards the surface of the convolution. Every here and there fine lateral branches come off from it, and ultimately it enters the stratum zonale, where, close to the surface, it ends by breaking up into a large number of fine terminal filaments, which spread out horizontally in every direction and interlace closely with the corresponding filaments of other pyramidal cells and with the other elements of this layer.

The axon of the cell descends, gives off collaterals, assumes a medullary sheath, and enters the central white core of the gyrus as a nerve fibre.

The **stratum zonale** is chiefly composed of fibres which run in a tangential direction, or, in other words, parallel to the surface. These form an interlacement of considerable density and extreme complexity. The elements which for the most part enter into the formation of this feltwork are: (1) the terminal filaments of the apical dendrites of the pyramidal cells; (2) the terminal filaments of certain corticipetal fibres, which enter the cortex from the white centre of the gyrus; (3) the axons of certain small cells peculiar to this stratum; (4) the axons of the cells of Martinotti. Spread over the surface of this tangential interlacement of fibres, which constitutes the most important part of the stratum zonale, there is a thin layer of neuroglia which intervenes between it and the pia mater, which covers the convolution. The stratum zonale is not devoid of nerve-cells, although these are small and somewhat indefinite in their connexions. The most characteristic form is a small fusiform cell described by Cajal, which sends out from either end a long process and which lies in the deeper part of the layer. The long filamentous processes of this cell thread their way between the other fibres in a tangential direction and give off minute branches which pass towards the surface.

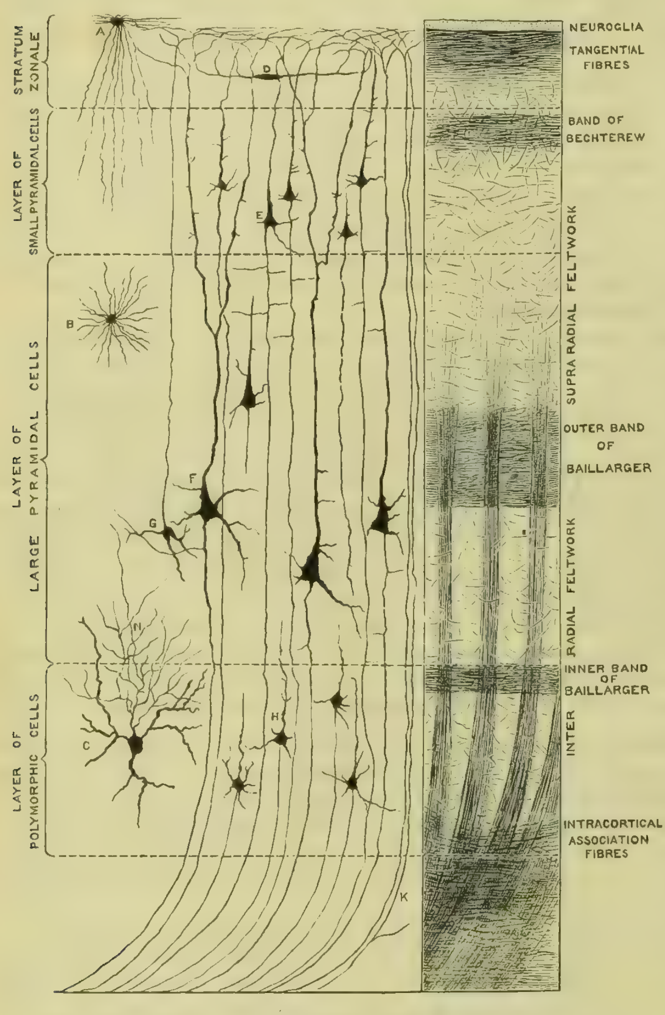


FIG. 405.—DIAGRAM TO ILLUSTRATE MINUTE STRUCTURE OF THE CEREBRAL CORTEX.

A. } Neuroglia cells.
B. }
C. Cell with short axon (N) which breaks up in a free arborisation.
D. Spindle-shaped cell in stratum zonate.
E. Small pyramidal cell.
F. Large pyramidal cell.
G. Cell of Martinotti.
H. Polymorphic cell.
K. Corticipetal fibres.

The **deepest layer of the cortex** contains the polymorphic cells. These cells are not large, and they present many different forms. Numerous dendrites proceed from the cells of this group, but none of these reach the stratum zonale, and in this respect the polymorphic cells offer a marked contrast to the pyramidal cells. The axons of the polymorphic cells, however, like those of the pyramidal cells, enter the white centre of the gyrus in the shape of nerve-fibres.

In addition to the cells characteristic of the several layers, there are two which may be found amongst the pyramidal or amongst the polymorphic cells. These are: (1) the cells of Golgi; (2) the cells of Martinotti.

A **cell of Golgi** has this peculiarity—that its axon, close to its origin, begins to divide, and very soon loses its individuality by breaking up into a perfect maze of branches, none of which pass far from the neighbourhood of the cell-body and none of which enter the stratum zonale.

The **cell of Martinotti** is small and is chiefly found in the deeper part of the cortex. Its leading peculiarity is, that its slender axon runs in a contrary direction to the axons of the pyramidal cells and of the polymorphic cells. In other words, it proceeds towards the

surface, and, entering into the stratum zonale, divides into terminal filaments, which spread out in the tangential interlacement characteristic of this layer.

Nerve Fibres.—The arrangement of the nerve-fibres can best be studied in vertical sections through the gray cortex, which have been specially treated with this end in view. In such preparations bundles of nerve-fibres are seen to radiate into the gray cortex from the surface of the white centre of the gyrus. As these proceed through the polymorphic layer into the layer of large pyramidal cells, they gradually become less distinct, and, finally, they disperse and are lost to view before they reach the layer of small pyramidal cells. In the intervals between the radiating bundles the polymorphic and large pyramidal cells are arranged in columns, and in the same intervals an open feltwork of intercrossing fibres is evident. After the radiating fibre-bundles have disappeared the same feltwork of fibres is visible in the gray matter, and consequently it is convenient to distinguish, with Edinger, an **inter-radial feltwork** and a **supra-radial feltwork** of fibres in the cortex. The fibres which enter into the composition of the different radial bundles vary in number from ten to twenty, and they gradually diminish in number as they proceed onwards. This diminution is due to their joining the various cells that they meet (both polymorphic and pyramidal) as their axons. The fibres in a given bundle also vary much in size, and it may be noticed that the largest fibres disappear in the vicinity of the large pyramidal cells, which shows clearly that it is with these that they are connected. But, in addition to cell-axons, the radial bundles contain fibres of an altogether different type, viz. corticipetal fibres, which pass through all the layers of the cortex and end in fine terminal filaments in the tangential interlacement of the stratum zonale.

The inter-radial and supra-radial feltwork is largely formed of the collaterals which issue from the axons. By a condensation of this feltwork the two bands of Baillarger are formed. The outer band, which is the broader and better marked, occurs in the deeper part of the layer of the large pyramidal cells. The inner band, when present, is formed in the superficial part of the layer of polymorphic cells.

Another condensation of the fibre-feltwork in the superficial part of the supra-radial region may be noted in certain localities. This is termed the **band of Bechterew**.

It has been noted that up to a certain point the tangential fibres increase in quantity as age advances, and there is reason to believe that upon the richness with which the gray cortex is supplied with fibres—more especially of the tangential variety—depends to some extent the intellectual capacity of an individual.

Whilst the general mass of the cortex for the most part conforms more or less closely to the ground-type described above, showing merely deviations characteristic of the different regions, there is one part of the cortex, viz. the cornu ammonis and the fascia dentata, in which the structural arrangement of the elements is very markedly different. To some extent this is due to the complicated manner in which, in this region, the cortex is folded upon itself.

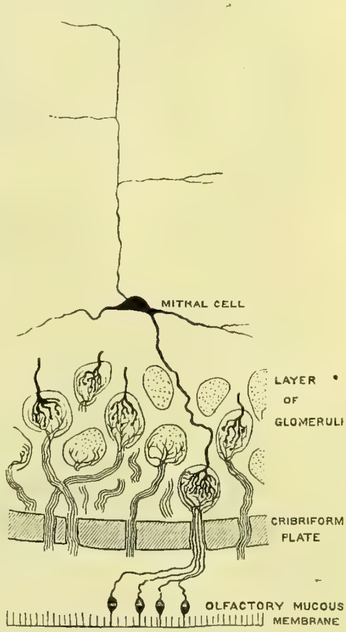


Fig. 406.—Diagram of the Minute Structure of the Olfactory Bulb.

The Olfactory Tract and Bulb.

The olfactory tract and bulb arise as a hollow outgrowth from the primitive cerebral vesicle. In many animals with a well-developed olfactory apparatus, the tract and bulb remain hollow; but in man the central cavity becomes obliterated, although traces of the original hollow persist in the shape of ependymal remains, visible in the centre of both tract and bulb. Outside these ependymal elements is a coating of white matter, upon which is laid the gray matter. The gray matter, however, is by no means uniformly distributed over the surface. In the tract, except along the dorsal edge, it is so thinly spread that it is hardly appreciable. In the bulb, on the other hand, there is very little gray matter on the dorsum, but a considerable quantity on the ventral surface; and it is into this that the delicate nerves which enter the cranium through the cribriform plate of the ethmoid bone sink. A brief description of the structure of this infrabulbar mass of gray matter, as well as of the connexions established by its elements, now becomes necessary.

The fibres of the delicate olfactory nerves are to be regarded as the axons of the olfactory cells of the olfactory mucous membrane. They enter the ventral surface of the olfactory bulb, and there each breaks up in an arborescent fashion into a tuft of terminal filaments. A thick dendrite from a mitral cell of the bulb passes down towards this terminal tuft, and, coming into contact with it, breaks up and terminates in a similar manner. In this way a large number of globular bodies, formed by the arborescent terminations of a mitral dendrite and of certain olfactory nerve-fibres, are formed. These are the **olfactory glomeruli** of the bulb. The mitral cells lie deeper in the olfactory bulb. Each gives off several dendrites and one axon. Only one dendrite enters into the formation of a glomerulus, but several nerve-fibres may be connected with such a body. It thus happens that, through its dendrite, a mitral cell may stand in connexion with several olfactory nerve-fibres. The axon of the mitral cell passes upwards to the white matter of the bulb, enters this, and is conducted through the tract towards the cerebral cortex.

White Medullary Centre of the Cerebral Hemisphere.

The white matter of the hemisphere which lies subjacent to the gray cortex is composed of medullated nerve-fibres, arranged in a very intricate manner. According to the connexions which they establish these fibres may be classified into three distinct groups, viz. (1) commissural fibres; (2) association fibres; and (3) projection fibres.

Commissural Fibres.—These are fibres which link together portions of the gray cortex of opposite cerebral hemispheres. They are arranged in three groups forming three definite structures, viz. the corpus callosum, the anterior commissure, and the psalterium or the hippocampal commissure.

The **corpus callosum** has in a great measure been already studied (p. 528). As it enters each hemisphere, its fibres spread out in an extensive radiation (the radiation of the corpus callosum). It thus comes about that every part of the cerebral cortex, with the exception of the bulbus olfactorii and the under and fore part of the temporal lobe, is reached by the callosal fibres. But it should be clearly understood that all the regions of the cortex do not receive an equal proportion of fibres; in other words, some cortical areas would appear to be more plentifully supplied than others. Another point of some importance consists in the fact that the callosal fibres do not, as a rule, connect together symmetrical portions of the gray cortex. As the fibres cross the mesial plane they become greatly scattered, so that most dissimilar parts of the cortex of opposite hemispheres come to be associated with each other.

Each callosal fibre arises in one hemisphere and ends by fine terminal arborisations in the cortex of the opposite hemisphere. It may arise in any one of three ways, viz. (1) as the axon of one of the cortical cells, either pyramidal or polymorphic; (2) as the collateral of a fibre of association; (3) as the collateral of a fibre of projection.

Many cases have been recorded in which, through congenital defect, the corpus callosum has not been developed. In the description of this structure on p. 528 attention has been called to a layer of callosal fibres which sweep over the posterior and descending horns of the lateral ventricle, so as to form the immediate outer wall of the cavity. This layer is called the **tapetum**, and it has been stated that when the corpus callosum is absent the tapetum is found in a well-developed condition. Further, it has been asserted that in cases where the corpus callosum has been experimentally destroyed the tapetum suffered no degeneration (Muratoff). Certain anatomists are, therefore, inclined to argue that the tapetum has little or no connexion with the corpus callosum. This assertion, however, cannot by any means be regarded as being proved. There is a large amount of evidence on the other side. Thus, Mingazzini has seen a case of failure of the corpus callosum which was accompanied by a corresponding defect in the tapetum, whilst softening of the splenium and the forceps major has been observed by Anton to be accompanied by a secondary degeneration of the tapetum. Further, the recent experimental evidence of Ferrier and Turner would appear to support the older view that the tapetum is associated in the closest manner with the corpus callosum.

The **anterior commissure** (commissura anterior) is a structure supplemental to the corpus callosum. It connects together the two olfactory lobes, and also portions of opposite temporal lobes. It presents a cord-like appearance and is arranged in

the form of a horse-shoe, the concavity of which looks backwards. The middle free portion is placed immediately in front of the anterior pillars of the fornix as they curve downwards, and also in intimate relation to the anterior end of the third ventricle. Posteriorly, the small portion of the anterior commissure which appears in the ventricle between the two pillars of the fornix is clothed with the ventricular ependyma; anteriorly, the commissure is connected with the lamina cinerea as it stretches from the optic chiasma upwards towards the rostrum of the corpus callosum.

The lateral part of the anterior commissure penetrates the cerebral hemisphere, and, gaining the lower part of the internal capsule, divides into two portions, viz. a small lower olfactory part and a much larger temporal part.

The **olfactory portion** of the anterior commissure is an exceedingly small fasciculus. It passes downwards and forwards, and finally enters the olfactory tract. It is composed (1) of true commissural fibres, which bind one olfactory bulb to the other; and (2) of other fibres, which connect the olfactory bulb of one side with the temporal lobe of the other side.

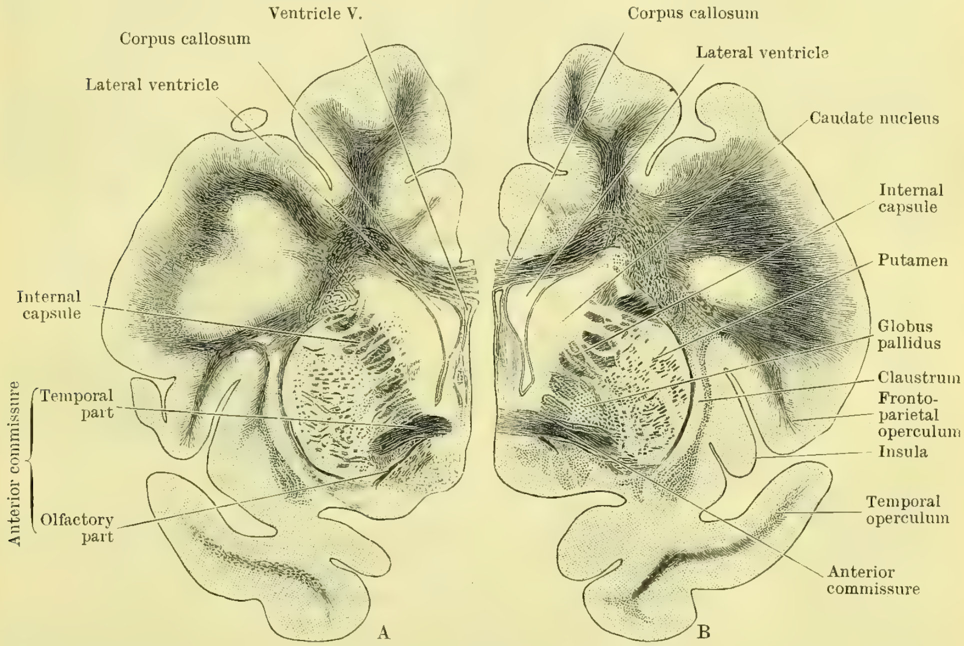


FIG. 407.—TWO CORONAL SECTIONS THROUGH THE CEREBRAL HEMISPHERES OF AN ORANG, IN THE PLANE OF THE ANTERIOR COMMISSURE.

A, Section through the left hemisphere in a plane a short distance behind B, which is a section through the right hemisphere.

The **temporal portion** is formed of almost the whole of the fibres of the commissure. It is carried transversely outwards, under the lenticular nucleus, until it gains the interval between the globus pallidus and the putamen. At this point it changes its direction and sweeps backwards. In coronal sections through the brain, behind this bend, the temporal portion of the anterior commissure appears as an oval bundle of fibres cut transversely and placed in close contact with the under surface of the lenticular nucleus (Fig. 403, p. 540). Finally, it turns sharply downwards on the outer aspect of the amygdaloid nucleus, and its fibres are lost in the white medullary centre of the temporal lobe. The precise part of the cerebral cortex with which these fibres stand in connexion is not known. When the lateral part of the anterior commissure is displayed by dissection, it is seen to be twisted like a rope.

The **psalterium**, or the **hippocampal commissure**, is composed of fibres which connect the cornu ammonis of one side with the corresponding structure of the opposite side. It is described on page 531.

Association Fibres.—The association fibres bind together different portions of

the cortex of the same hemisphere. They are grouped into long and short association bundles.

The greater number of the **short association fibres** pass between adjacent convolutions. They curve round the bottom of the sulci in U-shaped loops. Some of these occupy the deepest part of the gray cortex itself, and are termed *intracortical association fibres* (Fig. 405, p. 544); others lie immediately subjacent to the gray matter—between it and the general mass of the white matter—and receive the name of *subcortical fibres.* Many groups of short association fibres, instead of linking together contiguous convolutions, pass between gyri more or less remote. It is only after birth, when intellectual effort and education have stimulated different portions of the cortex to act in harmony and in conjunction with each other, that these association fibres assume their sheaths of medulla and become functional.

The **long association fibres** are arranged in bundles which run for considerable distances within the white medullary centre of the cerebral hemisphere, and unite districts of gray cortex which may be far removed from each other. The better known of these fasciculi are the following: (1) the uncinate; (2) the cingulum; (3) the superior longitudinal; (4) the inferior longitudinal; (5) the occipito-frontal.

The **fasciculus uncinatus** is composed of fibres which arch over the stem of the Sylvian fissure and connect the frontal pole, and the orbital convolutions of the frontal lobe, with the front portion of the temporal lobe.

The **cingulum** is a very well-marked and distinct band, which is closely associated with the limbic lobe. Beginning in front, in the region of the anterior perforated spot, it arches round the genu of the corpus callosum and is carried backwards on the upper surface of this structure at the place where its fibres pass into the

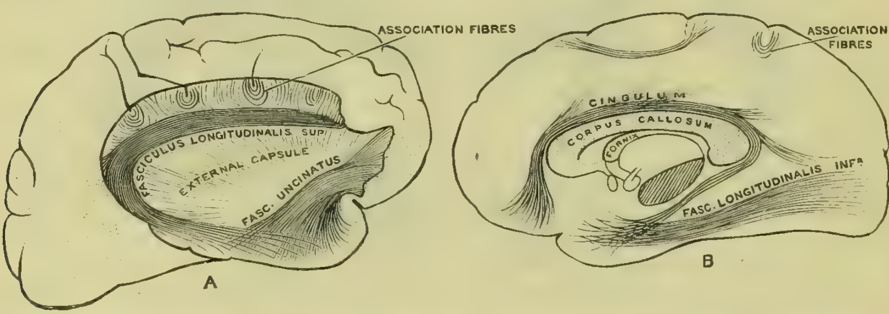


FIG. 408.—DIAGRAM OF THE LEADING ASSOCIATION BUNDLES OF THE CEREBRAL HEMISPHERE.
(Founded on the drawings of Déjerine.)
A. Outer aspect of hemisphere. B. Inner aspect of hemisphere.

callosal radiation. The cingulum, therefore, lies under cover of the callosal gyrus and stands in intimate relation to the white centre of this convolution (Fig. 392, p. 529). At the hinder end of the corpus callosum the cingulum turns round the splenium and is carried forwards, in relation to the hippocampal gyrus, to the uncus and the temporal pole. The cingulum is composed of several systems of fibres which only run for short distances within it.

The **fasciculus longitudinalis superior** is an arcuate bundle which is placed on the outer aspect of the foot or basal part of the corona radiata and connects the frontal, occipital, and temporal regions of the hemisphere. It lies in the base of the fronto-parietal operculum and sweeps backwards over the insular region to the posterior end of the Sylvian fissure. Here it bends downwards round the hinder end of the putamen and proceeds forwards in the temporal lobe, to reach its anterior extremity. As it turns downwards to reach the temporal lobe numerous fibres radiate from it into the occipital lobe.

The **fasciculus longitudinalis inferior** is a very conspicuous bundle which extends along the whole length of the occipital and temporal lobes (Fig. 392, p. 529). In the occipital lobe it is placed on the outer aspect of the optic radiation, which takes a similar direction and from which it is distinguished by the greater coarseness of its fibres (Figs. 397, p. 535; 400, p. 538; 409, p. 550). It is not present in the macaque monkey (Ferrier and Turner), but is well developed in the orang and the chimpanzee.

The **fasciculus occipito-frontalis** is a bundle of fibres which runs in a sagittal direction in intimate relation to the lateral ventricle (Fig. 403, p. 540). It has been pointed out (Forel, Onufrowicz, and others) that, in cases where the corpus callosum fails to develop, the tapetum remains apparently unaffected, and Déjerine has endeavoured to prove that the fibres of this layer really belong to the fasciculus occipito-frontalis. According to Déjerine, the fasciculus occipito-frontalis lies on the inner aspect of the corona radiata in intimate relation to the caudate nucleus, and posteriorly it spreads out over the upper and outer aspect of the lateral ventricle, immediately outside the ependyma, where it constitutes the tapetum (see p. 546). There is a considerable amount of literature dealing with this subject, and the most probable explanation of the difficulty would appear to be that the tapetum is composed of fibres derived from both the corpus callosum and the fasciculus occipito-frontalis of Déjerine.

Projection Fibres.—The projection fibres are those which connect the cerebral cortex with nuclear masses placed at a lower level. The great bulk of these fibres are found in the corona radiata. This has already been seen to be formed by the continuation upwards of the internal capsule (p. 542). In the corona radiata the fibres which, lower down, are gathered together in the compact mass which constitutes the internal capsule, radiate in every direction, intersect the radiation of the corpus callosum, and finally reach every region of the cortex. Although the fibres of the corona radiata represent the chief bulk of the projection fibres, it should also be borne in mind that a certain number gain the cortex by a different route, notably through and under the lenticular nucleus and by the path offered by the external capsule.

The projection fibres of the cerebral hemisphere may be classified into (1) corticipetal, and (2) corticifugal groups; and under these headings the following great strands may be arranged:—

Corticipetal Projection Strands.	Corticifugal Projection Strands.
1. Thalamo-cortical.	1. The pyramidal or great motor tract.
2. The fillet system of fibres.	2. The fronto-pontine strand.
3. The superior cerebellar peduncle.	3. The temporo-pontine strand.
4. Corticipetal fibres of the optic radiation.	4. The corticifugal fibres of the optic radiation.
5. The auditory radiation.	

The **great motor** or **pyramidal tract** is composed of fibres which arise from pyramidal cells in that portion of the cortex which is spread over the Rolandic area, or, in other words, in the district immediately in front of and immediately behind the fissure of Rolando. The fibres descend through the corona radiata into the posterior limb of the internal capsule. From this point the further course of the pyramidal tract has been traced, viz. through the central part of the crusta of the crus cerebri, the ventral part of the pons, and the pyramid of the medulla oblongata. At the level of the foramen magnum it decussates in the manner already described and enters the spinal cord as the crossed and direct pyramidal tracts. The fibres composing these end in connexion with the ventral or motor column of cells, from which the fibres of the anterior roots of the spinal nerves arise.

The **fronto-pontine strand** is composed of fibres which arise as the axons of the cells in the cortex which covers the portion of the frontal lobe, which lies in front of the præcentral furrows. It descends in the anterior limb of the internal capsule, enters the mesial part of the crusta of the crus cerebri, through which it gains the ventral part of the pons. In this its fibres end, by forming arborisations around the cells of the nucleus pontis.

The **temporo-pontine tract** consists of fibres which spring from the cells of that part of the cortex which covers the middle portions of the two upper temporal convolutions. It probably represents a corticifugal tract belonging to the auditory system, seeing that it springs to some extent from the auditory cortical area. The temporo-pontine tract passes inwards under the nucleus lenticularis, enters the retrolenticular part of the hinder limb of the internal capsule, and thus gains the outer part of the crusta of the crus cerebri. From this it descends into the ventral part of the pons, in which it ends in the nucleus pontis.

The **optic radiation** forms a very definite and easily demonstrated tract of

longitudinally-directed fibres in the white medullary centre of the occipital lobe. It lies on the outer side of the ventricular cavity, from which it is separated by the fibres of the tapetum and the ependyma of the ventricle (Figs. 397, p. 535; and 400, p. 538). To the outer side of, and applied closely to, the optic radiation is another longitudinal tract of fibres in this part of the medullary centre of the cerebral hemisphere, viz. the inferior longitudinal association bundle; but the fibres of the latter fasciculus are coarser and are stained more deeply by the Pal-Weigert method, and thus they can, as a rule, be easily distinguished from the optic radiation. Traced in a backward direction, the fibres of the optic radiation disperse and pass to the cortex of the occipital lobe on both its mesial and outer aspects. This is a matter of interest, seeing that the visual centre is placed in this cortical district, and more particularly on the mesial aspect in the immediate neighbourhood of the calcarine fissure (Flechsig and Henschen). When the optic radiation is followed in a forward

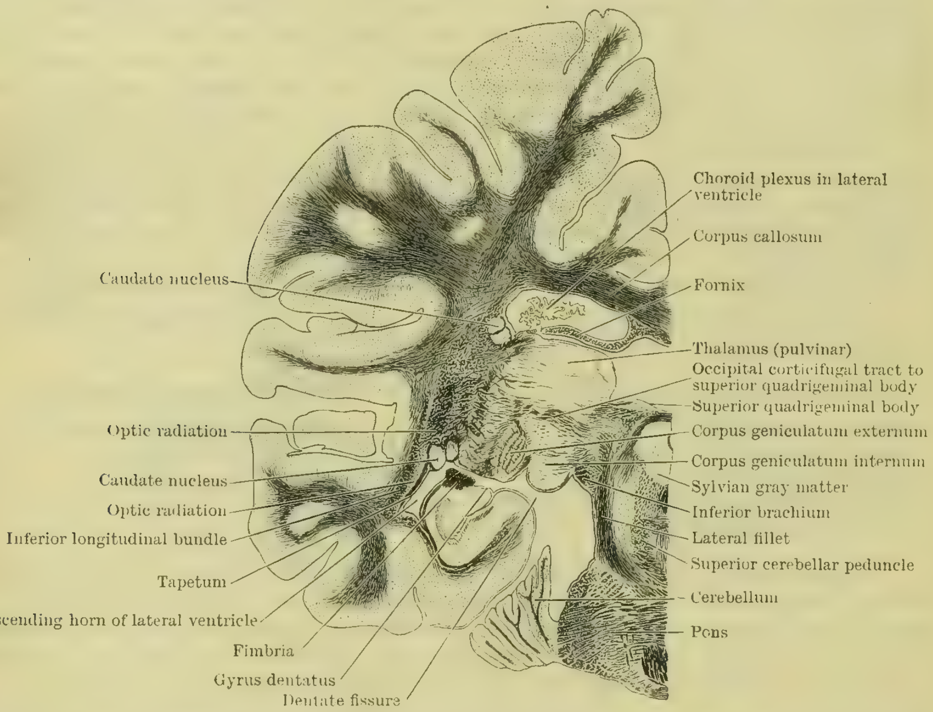


FIG. 409.—CORONAL SECTION THROUGH THE LEFT SIDE OF THE CEREBRUM, MESENCEPHALON, AND PONS, IN THE REGION OF THE PULVINAR OF THE THALAMUS AND THE CORPORA GENICULATA (Chimpanzee; Weigert-Pal specimen).

direction it is seen to enter the retrolenticular part of the posterior limb of the internal capsule, from whence its fibres pass to the pulvinar of the optic thalamus, to the corpus geniculatum externum and the superior quadrigeminal body.

As we have noted, the optic radiation is composed partly of corticifugal and partly of corticipetal fibres (p. 511). The former arise from cells in the occipital cortex and end in the pulvinar and the superior quadrigeminal body; the corticipetal fibres arise in the pulvinar and in the corpus geniculatum externum and end in the occipital cortex (Ferrier and Turner).

The system of fibres which belong to the **mesial fillet** and the **superior cerebellar peduncle** have been already more or less fully dealt with (pp. 494 and 497). The **fillet system** represents the continuation upwards of the posterior columns of the cord. The first nuclear internodes in the system are met with in the medulla in the shape of the cuneate and gracile nuclei. It is here that the fillet first takes definite shape, and, as it passes upwards through the tegmental part of the medulla and pons, it receives many additions to its strength in the form of fibres from the nuclei of termination of the afferent cranial nerves. Finally, passing through the tegmentum of the mesencephalon, it reaches the subthalamic region and enters the ventral aspect of

the thalamus. This may be looked upon as being the second internode laid across the path of the fillet, and many of its fibres end in arborisations around the thalamic cells. Still, it is probable that a proportion find their way directly through the thalamus, and, gaining the hinder limb of the internal capsule, they are carried up through the corona radiata to end in the Rolandic area, and more particularly in the posterior central convolution.

The **fibres of the superior cerebellar peduncle** encounter two nuclear internodes as they pass towards the cerebral cortex, viz. the red tegmental nucleus and the optic thalamus (p. 494). As in the case of the fillet, however, it is believed that many of the fibres gain the internal capsule, and, without break or interruption, proceed up through the corona radiata, to end in the cortex of the Rolandic area.

The **fibres of the auditory radiation** arise as the axons of cells situated in the internal geniculate body. They enter the retrolenticular part of the posterior limb of the internal capsule and proceed under the lenticular nucleus towards the temporal lobe. Here they end in the area of cortex which constitutes the auditory centre. This corresponds to the middle portion of the superior temporal convolution, and also to the rudimentary transverse gyri of Heschl, which are present on the insular surface of the temporal operculum.

The **thalamo-cortical system** includes the fibres which arise within the thalamus and which proceed to all parts of the cortex. They are sufficiently described at p. 504.

The remarkable researches of Flechsig have added greatly to our knowledge of the different tracts of fibres in the cerebral hemisphere. By studying the periods at which these tracts myelinate he has been able to note the manner in which the different areas of the cortex are bound together and also linked on to subjacent centres. He has arrived at a completely new and highly important conception regarding the functional value of different districts of the cortex, founded upon their anatomical connexions. He recognises four sense areas in the cortex, viz. the somæsthetic area, the visual area, the auditory area, and the olfactory area.

The **somæsthetic area** is the field of general sensibility and is the most extensive of all. It includes the two central convolutions, the posterior portions of the three frontal convolutions, the paracentral convolution, and the adjoining part of the callosal convolution.

The **visual area** is placed on the inner aspect of the occipital lobe, and more particularly in the immediate neighbourhood of the calcarine fissure.

The **auditory area** corresponds to the middle third of the superior temporal convolution and to the transverse gyri of Heschl.

The **olfactory area** includes the locus perforatus anticus, the trigonum olfactorium, the anterior part of the callosal convolution, and the uncus.

These sense areas are peculiarly rich in their supply of projection fibres, and each is provided with an extensive system of both corticifugal and corticipetal fibres. Thus the somæsthetic area

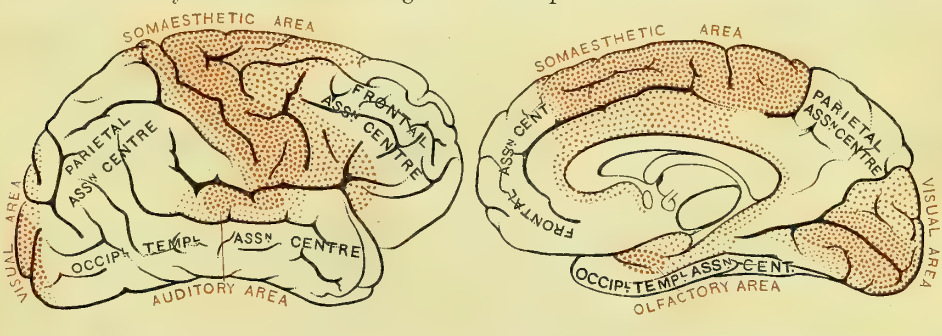


FIG. 410.—DIAGRAMS to show Flechsig's sensory and association areas on the surface of the cerebral hemisphere.

is the field where the motor pyramidal tract takes origin and within which the tracts of general sensibility end. The visual area has the corticipetal and corticifugal fibres of the optic radiation. The auditory area has the corticipetal auditory radiation and also the corticifugal temporopontine tract. In man the olfactory area is feebly developed, and Flechsig has not yet been able to establish, with certainty, its corticipetal and corticifugal projection tracts.

The sense areas differ greatly from each other in the extent of cerebral surface which they cover. The size in each case is in strict conformity with the peripheral area with which each is in connexion. It can easily be understood, therefore, how the somæsthetic area, representing as it does on the cortex all the parts of the body outside the special organs of sense, from which sensory nerves proceed, should be so large. Further, it is manifest why the visual sensorial area,

which in the cortex is the corresponding part to the retina, should be of greater extent than the auditory field, which represents the cochlea, and the olfactory area, which represents a small amount of olfactory mucous membrane in the nasal chamber.

The four sensorial areas, taken together, only form about one-third of the entire cerebral surface. The remaining two-thirds of the cortex constitute what Flechsig has termed the **association centres.** The great extent of these in man must be regarded as a special human characteristic. These centres differ from the sensorial areas in being exceedingly poorly provided with projection fibres. They have little direct connexion with the centres which lie at a lower level. Indeed, the only direct bond of union over a very large extent of these association areas with lower centres consists of the thalamo-cortical fibres, which pass to them from the thalamus. But, on the other hand, they are rich in association fibres, and are linked in the most complete and perfect manner by these fibres to the sensorial areas.

Flechsig regards these association areas as constituting the portions of cortex in which the higher intellectual activities are carried on, and he further believes that they exercise an important controlling influence over the sense areas. More particularly is this control exhibited in the case of the great somæsthetic area within which the influence of all bodily impressions is received and transformed into consciousness, and within which the impulses which are thereby excited take definite form. These impulses, according to Flechsig, are, in a measure, in all properly-balanced minds, held in subjection by the higher feelings, which assume shape in the association centres.

In his study of the fœtal and infantile brain Flechsig has shown that the fibres of the sensory paths become medullated in the first instance; then the corticifugal fibres which go out from the sense areas assume their sheaths of myelin; and, further, that it is not until a month after birth, and after the projection fibres in connexion with the sense areas are myelinated, that the association areas become linked on by medullated association fibres with the sense areas.

Development of the Parts derived from the Fore-brain.

It has been previously noted that the fore-brain very early shows an obscure subdivision into a front portion, termed the telencephalon, and a hinder part, called the diencephalon, which corresponds more nearly to the original cavity of the fore-brain. The cavity of third ventricle is derived from both, and stretches forwards, therefore, to the lamina terminalis, which in its lower part is represented in the adult by the lamina cinerea.

The lateral wall of both sections of the primitive fore-brain shows very distinctly the subdivision into a dorsal or alar and a ventral or basal lamina. The groove which indicates this separation is the sulcus of Monro, and is evident even in the adult brain.

Alar Lamina.—The alar part of the lateral wall of the *telencephalon* is pushed out to form the diverticulum, which ultimately constitutes the cerebral hemisphere, and thus from a very early period the primitive position of this part of the lateral wall is indicated by the wide foramen of Monro, or aperture of communication between the cavity of the cerebral hemisphere and the third ventricle.

The alar part of the lateral wall of the *diencephalon* is utilised for the development of the thalamus, the epithalamus, and the metathalamus. Of these the optic thalamus is derived from the anterior and by far the greatest part of the alar wall. It arises as a large oval swelling, which gradually approaches its fellow of the opposite side, and thus diminishes the width of the third ventricle. Finally, the two bodies come into contact in the mesial plane and cohere over an area corresponding to the gray commissure. This occurs about the end of the second month.

From that section of the lateral wall to which the name of metathalamus is given the two geniculate bodies arise. Each of these shows, in the first place, as a depression on the inside, and a slight elevation on the outside, of the wall of the diencephalon. As the thalamus grows backwards, it encroaches greatly upon the territory occupied by the geniculate bodies. It thus comes about that in the adult brain the internal geniculate body seems to hold a position on the lateral aspect of the mesencephalon, whilst the external geniculate body, viewed from the surface, appears to be a part of the thalamus.

From the epithalamic region of the wall of the diencephalon are developed the pineal gland, its peduncle, and the habenular region. These parts are relatively much more evident in the embryonic than in the adult brain. The pineal body is developed as a diverticulum of the posterior part of the roof of the diencephalon. Viewed from the dorsal aspect of the brain-tube, this diverticulum shows in the first instance as a rounded elevation, from either side of which a broad ridge runs forwards. This ridge becomes the tænia thalami, whilst in the region of its junction with the pineal elevation the trigonum habenulæ takes shape. The pineal diverticulum ultimately becomes solid, but a small portion of the original cavity is retained as the recessus pinealis of the third ventricle.

Basal Lamina.—The part of the diencephalon and telencephalon which lies below the level of the sulcus of Monro retains its primitive form, and undergoes only slight change. Consequently, when this region in the adult brain is compared with the corresponding region in the embryonic brain, the resemblance between the two is very striking.

In the fore-brain, therefore, it is the alar lamina which plays the predominant part in the formation of the cerebrum. The value, also, of the basal part of the wall of this portion of the neural tube is still further reduced by the fact that it no longer contains the nuclei of origin of efferent nerves. The highest of these nuclei (the oculo-motor) is placed in the mesencephalon.

The region of the fore-brain which lies below the sulcus of Monro is termed the hypothalamus. The part of this which corresponds to the diencephalon is called the pars mammillaris hypothalami, whilst the part in front, which belongs to the telencephalon, receives the name of pars optica hypothalami.

From the pars mammillaris hypothalami are derived the corpus mammillare and a portion of the tuber cinereum. With the pars optica hypothalami are associated the following parts, viz. the tuber cinereum, with the infundibulum and the cerebral part of the pituitary body, the optic chiasma, the optic recess, and the lamina cinerea.

The corpora mammillaria form, in the first instance, a relatively large downward bulging of the floor of the brain-tube. As development goes on this bulging becomes relatively small, and about the fourth month the single projection becomes divided into the two tubercles.

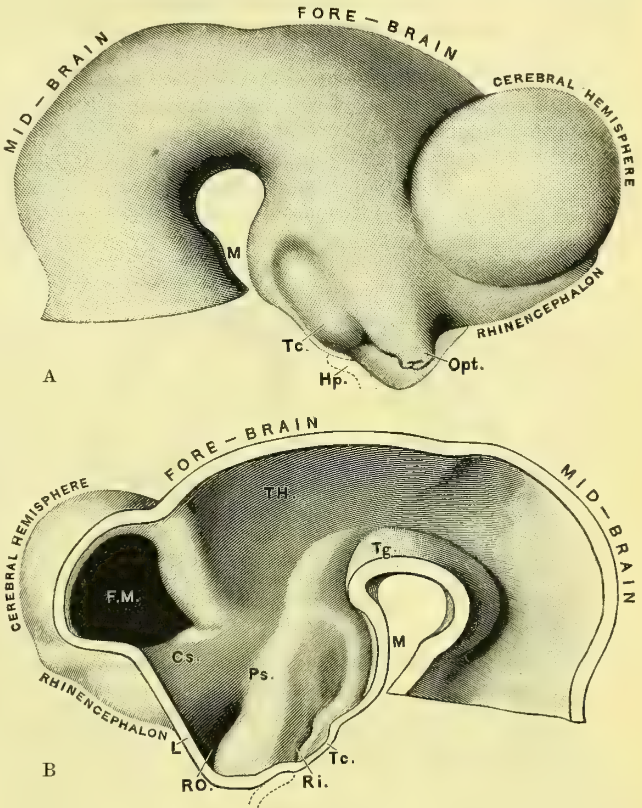


FIG. 411.—TWO DRAWINGS OF THE EMBRYONIC BRAIN (by His).

A, Reconstruction of the fore-brain and mid-brain of His's embryo KO; profile view. B, Same brain as A, divided along the mesial plane and viewed upon its inner aspect.

M, Mammillary eminence; T.c, Tuber cinereum; Hp, Hypophysis (pituitary diverticulum from buccal cavity); Opt, Optic stalk; TH, Optic thalamus; Tg, Tegmental part of mesencephalon; P.s, Pars subthalamica; C.s, Corpus striatum; F.M, Foramen of Monro; L, Lamina terminalis; R.O, Recessus opticus; R.i, Recessus infundibuli.

The infundibulum and posterior or cerebral lobe of the pituitary body are developed as a hollow downward diverticulum of the floor of the telencephalon (p. 508). A portion of the original cavity is retained in the upper part of the infundibulum, and constitutes the infundibular recess in the floor of the third ventricle.

The optic nerve is chiefly formed by the passage of fibres backwards from the retina in the wall of the original optic stalk, whilst the chiasma takes form by the transit of fibres across the middle line in front of the infundibulum and behind the optic recess. To a large extent these fibres are derived from the optic nerve. The optic recess of the third ventricle marks the spot where the hollow optic vesicle originally bulged out from the lower and lateral part of the fore-brain, and in the adult it therefore represents a portion of the primitive cavity of the tubular stalk of the optic vesicle. In the course of development the optic nerve fibres, which appear in the stalk of the optic vesicle to form the optic nerve, seek an attachment much further back, and through the optic tract they are even carried as far as the mesencephalon.

The **roof of the fore-brain** remains thin, and does not proceed to the development of nervous elements, except in its posterior part. Here it forms the pineal body and the

posterior commissure. In front of these structures the roof of the fore-brain is epithelial, and remains so during life. It constitutes the epithelial roof of the third ventricle, and it becomes involuted along the middle line into the cavity by the choroid plexuses of the ventricle. The posterior commissure appears as a transverse thickening at the bottom of a transverse groove which appears in the roof of the early brain-tube behind the pineal diverticulum.

Cerebral Hemisphere.—The cerebral hemisphere is derived entirely from the alar section of the lateral wall of the telencephalon. From this it grows out and soon assumes very large dimensions. At first it grows forwards and upwards, and a distinct fissure, the early incisura longitudinalis cerebri, appears between the cerebral hemispheres of opposite sides. The separation of the two cerebral vesicles by the longitudinal fissure begins at the end of the first month. This fissure becomes occupied by mesoblastic tissue,

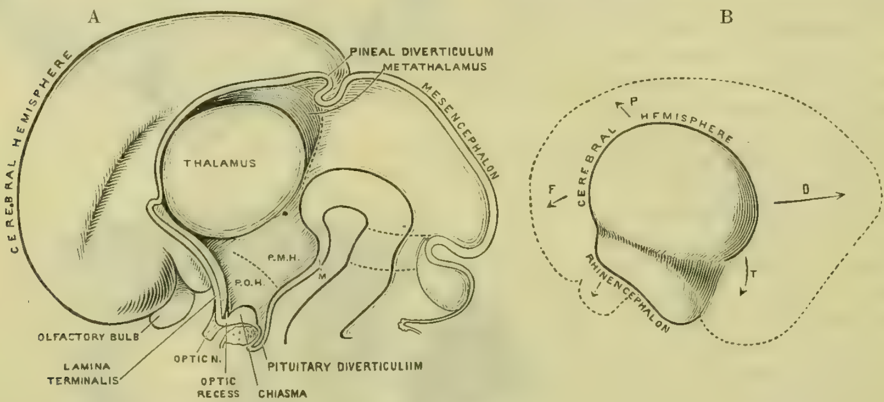


FIG. 412.—TWO DRAWINGS BY HIS, illustrating the development of the human brain.

A, Median section through a fœtal human brain in the third month of development.
B, Schema showing the directions in which the cerebral hemisphere expands during its growth.

P.M.H. Pars mammillaris hypothalami. M. Mammillary region. O. Occipital lobe.
P.O.H. Pars optica hypothalami. F. Frontal lobe. T. Temporal lobe.
P. Parietal lobe.

which later on forms the falx cerebri. The cerebral hemisphere, in its further growth, is carried progressively backwards over the hinder parts of the developing brain. At the end of the third month it has covered the optic thalamus. A month later it reaches the corpora quadrigemina, and by the seventh month it has not only covered these but also the entire upper surface of the cerebellum.

At the end of the first month the **rhinencephalon** or **nasal brain** begins to be marked off from the cerebral vesicle. It is situated below the cerebral vesicle, and is joined to the corresponding region of the opposite side by the lamina cinerea. Very soon the rhinencephalon is divided by a constriction or furrow, termed by His the *fissura prima*, into an anterior and a posterior part. From the anterior part the olfactory tract and bulb grows out in the form of a hollow diverticulum, whilst the basal part of the same division of the rhinencephalon forms the olfactory trigone and the area of Broca (p. 528). The posterior part of the rhinencephalon furnishes the anterior perforated space and the gyrus subcallosus.

In the floor of the hollow cerebral hemisphere a thickening takes origin, and this ultimately is developed into the corpus striatum. On the outer surface of the vesicle this thickening is seen to correspond to a depression which constitutes the early Sylvian fossa, the further development of which is described on p. 515.

In the earlier stages of its development the cerebral hemisphere is a thin-walled vesicle with a relatively large cavity, which represents the primitive condition of the lateral ventricle. At first the vesicle is bean-shaped and the cavity is curved. At this stage the outline is very similar to that presented by the cerebral hemisphere of a quadruped, and there is little or no trace of an occipital lobe or of a posterior horn of the lateral ventricle. As development goes on, however, the occipital portion of the hemisphere grows backwards over the cerebellum in the shape of a hollow protrusion, and a distinct occipital lobe enclosing the posterior horn of the lateral ventricle is the result. This developmental stage, which is distinctive of man and the apes, begins about the fourth month.

On the mesial aspect of the cerebral hemisphere, in the early stages of its development, an invagination of the wall of the vesicle takes place into the cavity immediately above

and behind the large foramen of Monro. This is the choroidal fissure, and the fold of the cerebral wall, which is thus thrust into the cavity, remains thin and entirely epithelial. After a time mesoblastic tissue from the great longitudinal fissure finds its way into the choroidal fissure and occupies the interval between the two thin layers which form the fold. This mesoblastic tissue forms the choroid plexus of the lateral ventricle, and in the early stages of the hemisphere it is so voluminous that it fills up the relatively large cavity of the lateral ventricle.

Development of the gyri and sulci.—From the beginning of the third month of development to about the end of the fourth month the surface of the cerebral hemisphere may present a number of linear and radially disposed fissures both upon its outer and its mesial aspects. These are produced by deep infoldings of the thin wall of the cerebral vesicle, and, with one or two exceptions, they entirely disappear when the fifth month of development is reached. At this period the cerebral surface again becomes smooth. They are therefore termed the **transitory fissures**. Only one permanent fissure, viz. the hippocampal, is with any degree of certainty lineally connected with one of these transitory fissures. Two, as a rule, occupy the ground which is later on held by the parieto-occipital and the calcarine fissures, of which they may be regarded as the precursors, but it is likely that in most cases they are obliterated before their permanent successors appear upon the stage.

At the time when the transitory fissures make their appearance, and during the whole period that they exist, it is important to note that the outer surface of the growing brain is applied closely to the deep surface of the enclosing cranial capsule. It therefore appears likely that the infolding of the cerebral wall, which produces the transitory fissures, is caused by a growth antagonism between the cranium and the enclosed cerebral vesicle. The cerebral vesicle, growing more rapidly than the cranium, has to accommodate itself to the restricted space in which it is placed by the infolding of its thin wall.

In an important memoir by Hochstetter the existence of these transitory fissures in the brain of the living fœtus is denied. The arguments advanced in favour of this view are very striking, but they do not explain all the circumstances of the case.

After the occipital lobe is fully formed and the fifth month is reached, all growth antagonism between the cranial capsule and the enclosed cerebral vesicle ceases. The surface of the cerebral hemisphere becomes smooth, and the cranium, growing for a time more rapidly than the brain, leaves a relatively wide space between the cerebral surface and the surrounding cranial envelope. This is occupied by sodden subarachnoid tissue, and when this stage is reached (in the latter part of the fifth month) the permanent fissures and gyri begin to make their appearance. The incomplete sulci owe their origin to the upheaval of the cerebral cortex on either side of the appearing fissures, and the gyri which bound them are formed as the result of an exuberance of surface growth in localised areas. Owing to the wide interval between the cranial wall and the surface of the cerebral hemisphere, the particular surface areas which grow and foreshadow the future gyri suffer no restriction, and they take the form of rounded eminences which rise from the general surface level of the cerebral hemisphere. As growth goes on, however, the brain gradually assumes a bulk more nearly in accord with the cavity of the cranium, and the space for extension becomes more limited. Finally, about the beginning of the eighth month, the gyral elevations come into close contact with the cranial wall, and a second period of growth antagonism between the brain and its enclosing capsule is entered upon. As a result of this the gyri are pressed together, the fissures assume more definite shape, and the ordinary convolutionary forms make their appearance. So intimate, indeed, is the contact between the cerebral hemisphere and the skull capsule that the gyri, to some extent, produce an imprint on the deep aspect of the cranial bones.

As already explained, the complete fissures are produced by an infolding of the wall of the cerebral vesicle. One of these is a transitory fissure, viz. the external perpendicular fissure of Bischoff. This differs from the earlier transitory fissures described above in so far that it does not come into view until the end of the fifth month, when the latter have completely disappeared (p. 523).

Cerebral commissures.—The development of the cerebral commissures is surrounded with much difficulty, and cannot be said at the present moment to be fully understood. It would seem that the corpus callosum, the anterior commissure, and the fornix take origin in the thickened upper part of the lamina terminalis. The triangular interval which is left between these commissures is occupied by the septum lucidum, the precise nature of which is somewhat doubtful. Probably it is formed from the lamina terminalis,

and is drawn backwards into its characteristic triangular shape by the backward growth of the corpus callosum. The fifth ventricle arises as a mesial cleft within it, and at no time has any connexion with the proper ventricular system of the brain.

Weight of the Brain.

The average weight of the adult male brain may be said to be about 1360 grammes. The female brain weighs rather less, but this is to be expected from the smaller bulk of the female body. Probably the relative weight of the brain in the two sexes is very much the same. The variations met with in brain-weight are very great, but it is doubtful if normal intellectual functions could be carried on in a brain which weighs less than 960 grammes. In microcephalic idiots brains of extremely small size are met with.

THE MENINGES OF THE BRAIN AND SPINAL CORD.

The brain and spinal cord are enclosed within three membranes, which are termed the meninges or meningeal membranes. From without inwards these are: (1) the dura mater, (2) the arachnoid mater, and (3) the pia mater. The space between the dura mater and the arachnoid receives the name of subdural space, while the much more roomy interval between the arachnoid and the pia mater is called the subarachnoid space.

Dura Mater.

The dura mater is a dense and thick fibrous membrane which possesses a very considerable degree of strength. Its arrangement within the cranial cavity is so different from that within the spinal canal that it is customary to speak of it as consisting of two parts, viz. a cranial and a spinal, although in adopting this subdivision it must be clearly understood that both portions are continuous with each other at the foramen magnum.

Cranial Dura Mater (dura mater cerebri).—The cranial dura mater is adherent to the inner surface of the cranial wall, and performs a double office. It serves as an internal periosteum for the bones which it lines and constitutes an envelope for the brain. Its inner surface, which bounds the subdural space, is smooth and glistening, and is covered by a layer of endothelial cells. The outer surface, when separated from the cranial wall, is rough, this being due to numerous fine fibrous processes and blood-vessels which pass between it and the bones. Its degree of adhesion to the cranial wall differs considerably in different regions. To the vault of the cranium, except along the lines of the sutures, the connexion is by no means strong, and in the intervals between the fibrous processes which pass into the bone there are small lymph spaces (epidural spaces) where the outer surface of the membrane is covered by endothelial cells. So long as the sutures are open the dura mater is connected with the periosteum on the exterior of the skull, along the sutural lines, by a thin layer of fibrous tissue which intervenes between the bony margins. Around the foramen magnum, and to the floor of the cranium, the dura mater is very firmly adherent. This is more particularly marked in the case of the projecting parts of the cranial floor, as, for example, the petrous portions of the temporal bones, the clinoid processes, and so on. This firm adhesion in these regions is still further strengthened by the fact that the nerves, as they leave the cranium through the various foramina, are followed by sheaths of the fibrous dura mater. Outside the cranium these prolongations of the membrane blend with the fibrous sheaths of the nerves, and likewise become connected with the periosteum on the exterior. In the child, during the growth of the cranial bones, and also in old age, the dura mater is more adherent to the cranial wall than during the intermediate portion of life.

The cranial dura mater is composed of two layers intimately connected with each other, but yet capable of being demonstrated in most regions of the cranium. Along certain lines these two layers separate from each other so as to form channels lined by endothelium. These channels are the **venous blood-sinuses** which receive the

blood from veins which come from various parts of the brain. They are described in the section dealing with the Vascular System.

Strong fibrous partitions or septa are given off along certain lines from the deep

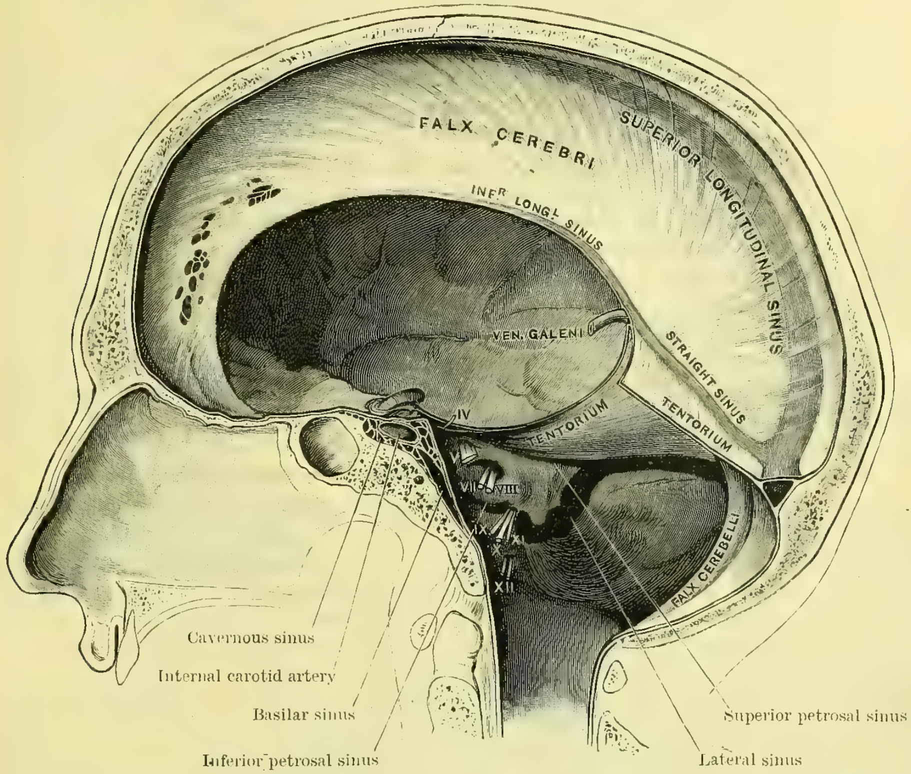


Fig. 413.—Sagittal Section through the Skull, a little to the Left of the Mesial Plane, to show the arrangement of the dura mater.
The cranial nerves are indicated by numerals.

surface of the dura mater. These project into the cranial cavity, and subdivide it partially into compartments which all freely communicate with each other, and each of which contains a definite subdivision of the brain. These septa are: (1) the falx cerebri; (2) the tentorium cerebelli; (3) the falx cerebelli; and (4) the diaphragma sellæ.

The **falx cerebri** is a sickle-shaped partition which descends in the great longitudinal fissure between the two hemispheres of the cerebrum. In front it is narrow, and attached to the crista galli of the ethmoid bone. As it is followed backwards it increases in breadth, and behind, it is attached along the mesial plane to the upper surface of the tentorium. The anterior narrow part of the falx is frequently cribriform, and is sometimes perforated by apertures to such an extent that it almost resembles lace-work. Along each border it splits into two layers, so as to enclose a blood sinus. Along its upper convex attached border runs the *great longitudinal sinus;* along its concave free border courses the much smaller *inferior longitudinal sinus;* whilst along its attachment to the tentorium is enclosed the *straight sinus.*

The **tentorium cerebelli** is a large crescentic partition of dura mater, which forms a membranous tent-like roof for the posterior cranial fossa, and thus intervenes between the posterior portions of the cerebral hemispheres and the cerebellum. It is accurately applied to the upper surface of the cerebellum. Thus its highest point is in front and in the mesial plane, and from this it slopes downwards towards its attached border. It is kept at a high degree of tension, and this depends on the integrity of the falx cerebri, which is attached to its upper aspect in the mesial plane.

The *posterior border* of the tentorium is convex, and is attached to the hori-

zontal ridge which marks the deep surface of the occipital bone. Beyond this, on each side, it is fixed to the postero-inferior border of the parietal bone, and then forwards along the superior border of the petrous portion of the temporal bone. From the internal occipital protuberance to the postero-inferior angle of the parietal bone this border encloses the *lateral blood sinus*, whilst along the upper border of the petrous bone it encloses the *superior petrosal sinus*. The *anterior border* of the tentorium is sharp, free, and concave, and forms with the dorsum sellæ an oval opening shaped posteriorly like a pointed arch. This opening receives the name of the **incisura tentorii**, and within it is placed the mesencephalon, or the stalk of connexion between the parts which lie in the posterior cranial fossa and the cerebrum. Beyond the apex of the petrous part of the temporal bone the two margins of the tentorium cross each other like the limbs of the letter X; the free margin is continued forwards, to be attached to the anterior clinoid process, whilst the attached border proceeds inwards, to be fixed to the posterior clinoid process.

The **falx cerebelli** is a small, sickle-shaped process of dura mater placed below the tentorium, which projects forwards in the mesial plane from the internal occipital crest. It occupies the notch which separates the two hemispheres of the cerebellum posteriorly. Inferiorly it bifurcates into two small diverging ridges which gradually fade away as they are traced forwards on either side of the foramen magnum.

The **diaphragma sellæ** is a small circular fold of dura mater which forms a roof for the pituitary fossa. A small opening is left in its centre for the transmission of the infundibulum.

Spinal Dura Mater (dura mater spinalis).—In the spinal canal the dura mater forms a tube which encloses the spinal cord, and which extends from the foramen magnum above to the level of the second or third piece of the sacrum below. It is very loosely applied to the spinal cord and the nerve-roots which form the cauda equina; in other words, it is very capacious in comparison with the volume of its contents. Moreover, its calibre is not uniform. In the cervical and lumbar regions it is considerably wider than in the dorsal region, whilst in the sacral canal it rapidly contracts, and finally ends by blending with the filum terminale externum, the chief bulk of which it forms. At the upper end of the spinal canal the spinal dura mater is firmly fixed to the third cervical vertebra, to the axis vertebra, and around the margin of the foramen magnum. In the sacral canal the filum terminale externum, with which it blends, extends downwards to the back of the coccyx, to the periosteum of which it is fixed. The lower end of the tube is thus securely anchored and held in its place.

Within the cranial cavity the dura mater is closely adherent to the bones, and forms for them an internal periosteum. As it is followed into the spinal canal its two constituent layers separate. The inner layer is carried downwards as the long cylindrical tube which encloses the spinal cord. The outer layer, which is much thinner, becomes continuous behind and on each side of the foramen magnum with the periosteum on the exterior of the cranium, whilst in front it is prolonged downwards into the vertebral canal in connexion with the periosteum and ligaments on the anterior wall of the canal. The spinal dura mater, therefore, corresponds to the inner layer of the cranial dura mater, and to it alone. It is separated from the walls of the spinal canal by an interval, the **epidural space**, which is occupied by soft fat and a plexus of thin-walled veins. In connexion with the spinal dura mater there are no blood-sinuses such as are present in the cranial cavity, but it should be noted that the veins in the epidural space, placed as they are between the periosteum of the spinal canal and tube of dura mater, occupy the same morphological plane as the cranial blood-sinuses. Another feature which serves to distinguish the spinal dura mater from the cranial dura mater consists in the fact that it gives off from its deep surface no partitions or septa.

The cylindrical tube of spinal dura mater does not lie absolutely free within the vertebral canal. Its attachments, however, are of such a character that they in no way interfere with the free movement of the vertebral column. On either side the spinal nerve-roots, as they pierce the dura mater, carry with them into the intervertebral foramina tubular sheaths of the membrane, whilst in front loose fibrous prolongations—more numerous above and below than in the dorsal region—connect the tube of dura mater to the posterior common ligament of the vertebral column. No connexion of any kind exists between the dura mater and the posterior wall of the spinal canal.

When the interior of the tube of spinal dura mater is inspected, the series of apertures of exit for the roots of the spinal nerves is seen. These are ranged in pairs opposite each intervertebral foramen.

Viewed from the inside of the tube of dura mater, each of the two roots of a spinal nerve is seen to carry with it a special and distinct sheath. When examined on the outside, however, the appearance is such that one might be led to conclude that both roots are enveloped in one sheath of dura mater. This is due to the fact that the two sheaths are firmly held together by intervening connective tissue. The two tubular sheaths remain distinct as far as the ganglion on the posterior root, and then blend with each other.

Subdural Space.—The dura mater and the arachnoid mater are closely applied to each other, and the capillary interval between them is termed the subdural space. It contains a minute quantity of fluid, which is just sufficient in amount to moisten the opposed surfaces of the two bounding membranes.

The subdural space in no way communicates with the subarachnoid space. The fluid which it contains is led into the venous blood-sinuses around the Pacchionian bodies, and thus gains exit. The subdural space is carried outwards for a very short distance on the various nerves which are connected with the brain and the spinal cord, and it has a free communication with the lymph paths present in these nerves. In the case of the optic nerve the sheath of dura mater is carried along its whole length, and with it the subdural space is likewise prolonged to the back of the eyeball.

The Arachnoidea.

The arachnoid mater is a very thin membrane, remarkable for its delicacy and transparency, which envelopes both the brain and the cord between the dura mater and the pia mater. The cranial part of the arachnoid mater or the **arachnoidea encephali**, except in the case of the great longitudinal and the Sylvian fissures, does

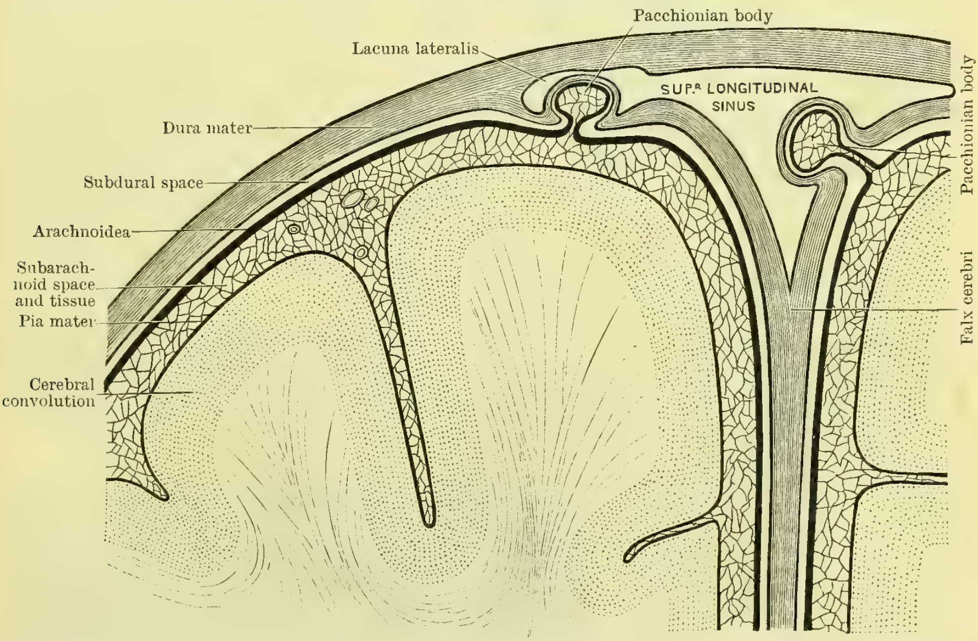


FIG. 414.—DIAGRAM to show the relations of the membranes of the brain to the cranial wall and the cerebral convolutions, and also of the Pacchionian bodies to the superior longitudinal sinus and the lateral lacunæ.

not dip into the sulci on the surface of the brain. In this respect it differs from the pia mater. It bridges over the inequalities on the surface of the brain. Consequently, on the basal aspect of the encephalon it is spread out in the form of a very distinct sheet over the medulla, the pons Varolii, and the hollow which lies in front of the pons, and in certain of these regions it is separated from the brain-surface by wide intervals.

The spinal part of the arachnoid mater or **arachnoidea spinalis**, which is directly continuous with the cranial arachnoidea, forms a loose wide investment for the

spinal cord. This arachnoidal sac is most capacious towards its lower part, where it envelopes the lower end of the cord and the collection of long nerve-roots which constitute the cauda equina.

As the nerves, both from the brain and the cord, pass outwards they receive an investment from the arachnoid, which runs for a short distance upon them and then comes to an end.

Subarachnoid Space (cavum subarachnoidale).—The interval between the arachnoidea and the pia mater receives the name of the subarachnoid space. It contains the cerebro-spinal fluid, and communicates freely through certain well-defined apertures with the ventricular cavities in the interior of the brain. Three of these (viz. the foramen of Majendie and another at the extremity of each lateral recess) are in connexion with the fourth ventricle; two are slit-like openings into the lateral ventricles, and are placed at the extremity of each descending horn.

Within the cranium the subarachnoid space is broken up by a meshwork of fine filaments and trabeculæ, which connects the two bounding membranes (viz. the arachnoidea and the pia mater) in the most intimate manner, and forms a delicate sponge-like interlacement between them. Where the arachnoidea passes over the summit of a cerebral convolution, and is consequently closely applied to the subjacent pia mater, the meshwork is so dense and the trabeculæ so short that it is hardly possible to discriminate between the two membranes. To all intents and purposes they form in these localities one lamina. In the intervals between the rounded margins of adjoining convolutions, however, distinct angular spaces exist, where the subarachnoid trabecular tissue can be studied to great advantage. These intervals on the surface of the cerebrum constitute numerous communicating channels which serve for the free passage of the subarachnoid fluid from one part of the brain to another. The larger branches of the arteries and veins of the brain traverse the subarachnoid space; their walls are directly connected with the subarachnoid trabeculæ, and are bathed by subarachnoid fluid.

In certain situations within the cranium the arachnoidea is separated from the pia mater by intervals of considerable width and extent. These expanded portions of the subarachnoid space are termed **cisternæ subarachnoidales**. In these the subarachnoid tissue is much reduced. There is no longer a close meshwork; the trabeculæ connecting the two bounding membranes take the form of long filamentous intersecting threads which traverse the spaces. All the subarachnoid cisterns communicate in the freest manner with each other and also with the narrow channels on the surface of the cerebrum.

Certain of these cisterns require special mention. The largest and most conspicuous is the **cisterna magna**. It is formed by the arachnoid membrane bridging over the wide interval between the back part of the under surface of the cerebellum and the medulla. It is continuous through the foramen magnum with the posterior part of the wide subarachnoid space of the cord.

The **cisterna pontis** is the continuation upwards on the floor of the cranium of the anterior part of the subarachnoid space of the spinal cord. In the region of the medulla it is continuous behind with the cisterna magna, so that this subdivision of the brain, like the spinal cord, is surrounded by a wide subarachnoid space.

In front of the pons Varolii the arachnoidea bridges across between the projecting temporal lobes, and covers in the deep hollow in this region of the brain. This space is called the **cisterna basalis,** and within it are placed the large arteries which take part in the formation of the circle of Willis. Leading out from the cisterna basalis there are certain wide subarachnoid channels. Two of these are prolonged into the Sylvian fissures, and in these are accommodated the middle cerebral arteries. Anteriorly the basal cistern passes into a space in front of the optic chiasma, and from this it is continued into the great longitudinal fissure above the corpus callosum. In this subarachnoid passage the anterior cerebral arteries are lodged.

The spinal part of the subarachnoid space is a very wide interval which is partially subdivided into compartments by three incomplete septa. One of these is a mesial partition called the **septum posticum**, which connects the pia mater covering the posterior aspect of the cord with the arachnoid mater. In the upper part of the cervical region the septum posticum is imperfect, and is merely represented by some strands passing between the two membranes; in the lower part of the cervical region and in the dorsal region it becomes tolerably complete. The other two septa are formed by the **ligamenta denticulata** which spread outwards from either side of the spinal cord. These will be described with the pia mater.

Pacchionian Bodies (granulationes arachnoidales).—When the surface of the dura mater is inspected after the removal of the calvaria, a number of small fleshy-looking excrescences, purplish-red in colour, are seen ranged in clusters on either side of the superior longitudinal sinus, and when this sinus is opened they are also observed protruding in considerable numbers into its interior. These are the Pacchionian bodies, and they are also found in smaller number and distinctly smaller size in connexion with other blood sinuses, such as the lateral sinus, the straight sinus, and the cavernous sinus. At first sight they appear to belong to the dura mater, but in reality they are projections from the arachnoidea. In the child they are exceedingly small and rudimentary, and it is only as life advances that they become large and conspicuous.

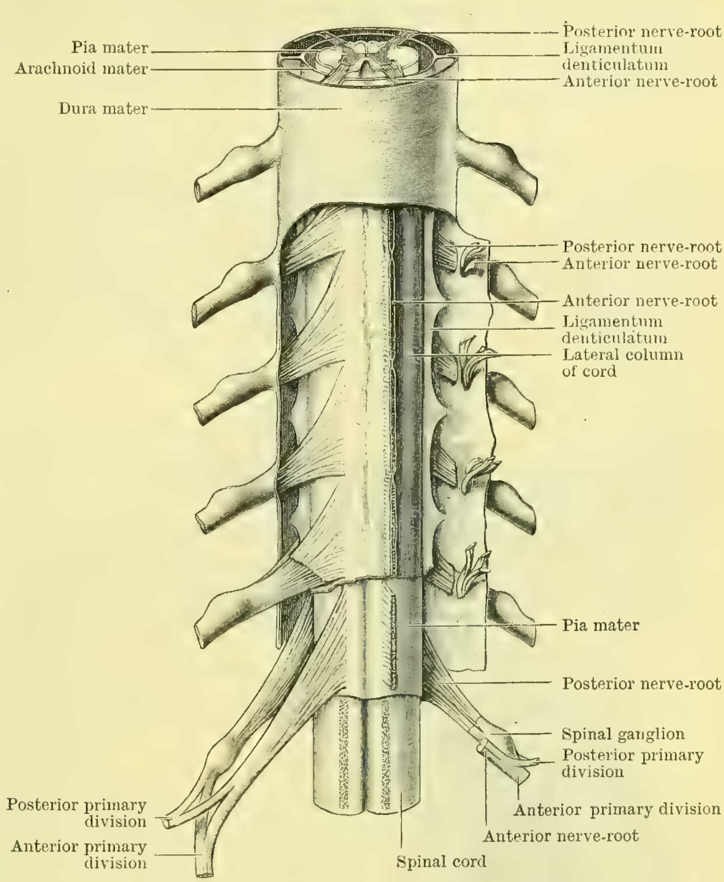


FIG. 415.—MEMBRANES OF THE SPINAL CORD, AND THE RELATIONS THEY PRESENT TO THE SPINAL NERVE-ROOTS (A. M. Paterson).

Each Pacchionian body is a bulbous protrusion of the arachnoid membrane. It is attached to the arachnoidea by a narrow pedicle, and into its interior is prolonged through this a continuation of the subarachnoid space and its characteristic meshwork. The Pacchionian bodies do not pierce the dura mater. As they push their way into a blood-sinus they carry before them a thin covering continuous with the sinus wall. On either side of the superior longitudinal sinus there are a number of irregular spaces in the dura mater which communicate with the sinus either by a small aperture or a narrow channel.

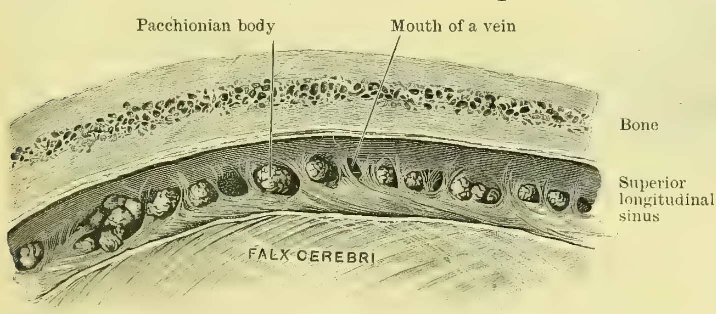


FIG. 416.—MESIAL SECTION THROUGH THE CRANIAL VAULT IN THE FRONTAL REGION. Displays the superior longitudinal sinus and the Pacchionian bodies protruding into it (enlarged).

These spaces are called the **parasinoidal sinuses** or the **lacunæ laterales**, and certain of the meningeal veins and some of the diploic veins open into them. Pacchionian bodies push themselves into the parasinoidal sinuses from below in such a manner that they receive a complete covering from the layer of dura mater which forms

the sinus floor. Nor does the bone escape. As the Pacchionian bodies enlarge they cause absorption of the cranial wall, and small pits are hollowed out on its deep surface for their reception. It must be clearly understood, however, that in such cases the Pacchionian body is separated from the bone by the following:—(1) A continuation round the Pacchionian body of the subdural space; (2) the thinned floor of the parasinoidal sinus; (3) the lumen of the sinus; and (4) the greatly thinned upper wall of the sinus.

The Pacchionian bodies have a special function to perform. Through them fluid can pass from the subarachnoid space into the venous sinuses with which they stand in connexion. Whenever the pressure of blood in the sinuses is lower than that of the fluid in the subarachnoid space and the ventricles of the brain, the cerebro-spinal fluid filtrates through the Pacchionian bodies into the blood sinuses. This is not the only way that subarachnoid fluid may obtain exit. The subarachnoid space is carried outwards for a short distance on the nerves in connexion with their arachnoidal sheaths, and communicates with the lymph channels of the nerves. This connexion is more complete in the case of the olfactory, the optic, and the auditory nerves, than in other nerves. A very free communication between the subarachnoid space and the lymphatics of the nasal mucous membrane is said to exist.

The Pia Mater.

The pia mater forms the immediate investment of the brain and cord. It is a delicate and very vascular membrane.

Pia mater encephali. — The pia mater which covers the brain is finer and more delicate than that which clothes the spinal cord. It follows closely all the inequalities on the surface of the brain, and in the case of the cerebrum it dips into each sulcus in the form of a fold which lines it completely. On the cerebellum the relation is not so intimate; it is only into the larger fissures that it penetrates in the form of folds.

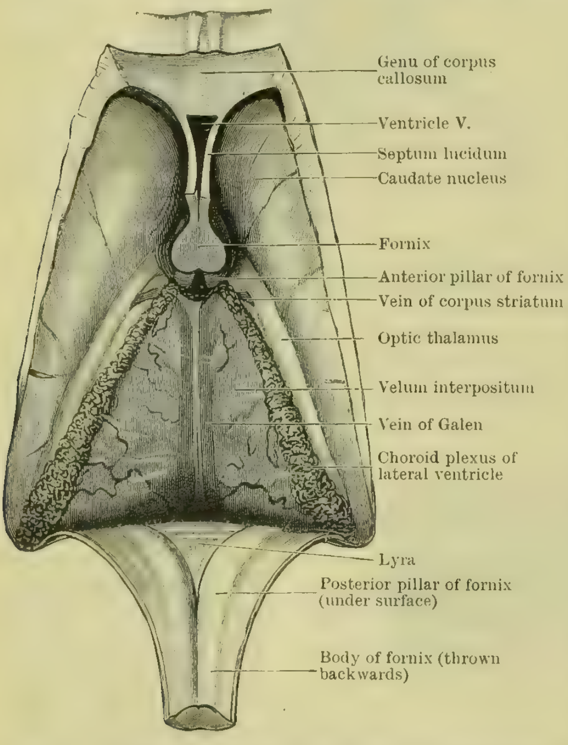


Fig. 417.—Dissection to show the Velum Interpositum, and the Parts in immediate relation to it.

The larger blood-vessels of the brain lie in the subarachnoid space. The finer twigs ramify in the pia mater before they proceed into the substance of the brain. As they enter they carry with them sheaths derived from the pia mater. When a portion of the membrane is raised from the surface of the encephalon, numerous fine processes are withdrawn from the cerebral surface. These are the blood-vessels with their sheaths, and they give the deep surface of the pia mater a rough and flocculent appearance.

As the pia mater is carried over the lower part of the roof or posterior wall of the fourth ventricle of the brain it receives the name of the **tela choroidea inferior**, and it is in connexion with this portion of the pia mater that the choroid plexuses of that cavity are developed. The tela choroidea superior or velum interpositum is a fold of pia mater which is invaginated into the brain, so that it comes to lie over the third ventricle and project in the shape of choroid plexuses into the lateral ventricles. This invagination requires special notice.

The **velum interpositum** (tela choroidea superior) is a double layer or fold of pia

mater which intervenes between the body of the fornix which lies above it and the epithelial roof of the third ventricle, and the two optic thalami which lie below it. Between its two layers are blood-vessels, and some subarachnoidal trabecular tissue. In shape the velum interpositum is triangular, and the narrow anterior end or apex reaches forwards as far as the foramina of Monro. The base lies under the splenium of the corpus callosum, and here the two layers of the velum separate and become continuous with the investing pia mater on the surface of the brain by passing out through a cleft called the **transverse fissure**.

Along each lateral margin the velum interpositum is bordered by the choroid plexus of the body of the lateral ventricle, which projects into the ventricular cavity from under cover of the free lateral margin of the fornix. It should be borne in mind that the epithelial lining of the ventricle gives a complete covering to the choroid plexus. Posteriorly the choroid plexus is continuous with the similar structure in the descending horn of the ventricle, whilst in front it narrows greatly, and becomes continuous across the mesial plane with the corresponding plexus of the opposite side, behind the epithelial layer which lines the foramen of Monro. From this median junction two much smaller choroid plexuses run backwards on the under surface of the velum interpositum, and project downwards into the third ventricle. These are the choroid plexuses of the third ventricle.

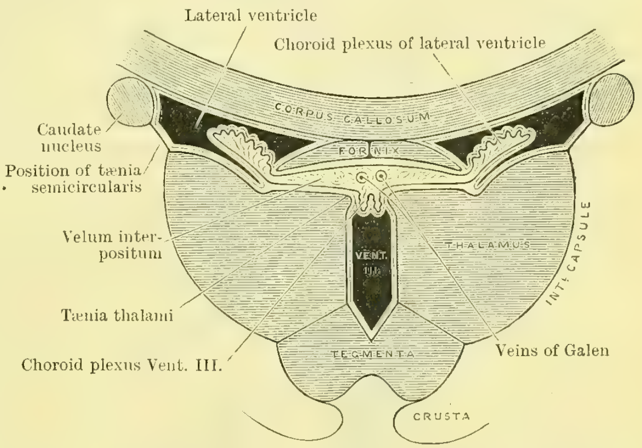


Fig. 418. — Diagrammatic Coronal Section through the optic thalami, and the parts in immediate relation to them. The intermediate part of the great transverse fissure holding the velum interpositum is seen, and also the manner in which this fissure is shut out from the lateral ventricles by the epithelium which covers the choroid plexus on each side.

The most conspicuous blood-vessels in the velum interpositum are the two **veins of Galen**, which run backwards, one on either side of the mesial plane. In front, each is formed at the apex of the fold by the union of the vein of the corpus striatum and a large vein issuing from the choroid plexus; behind, they unite to form the **vena magna Galeni**, and this pours its blood into the anterior end of the straight sinus (Fig. 413, p. 557).

The continuous cleft in the brain through which the velum interpositum and the choroid plexuses of the two descending horns of the lateral ventricles are introduced into the interior of the brain is sometimes called the **transverse fissure**. It consists of an upper intermediate part and two lateral parts. The former passes forwards between the corpus callosum and the fornix above and the roof of the third ventricle and the optic thalami below. It is limited on either side by the epithelial covering of the choroid plexuses which shuts out these structures from the cavity of the lateral ventricles. The lateral part is the **choroidal fissure**. This is continuous with the intermediate part, and has already been described in connexion with the descending horn of the lateral ventricle (p. 535).

Pia mater spinalis.—The pia mater of the cord is thicker and denser than that of the brain. This is largely due to the addition of an outside fibrous layer, in which the fibres run chiefly in the longitudinal direction. The pia mater is very firmly adherent to the surface of the cord, and in front it sends a fold into the antero-median fissure of the cord. The septum which occupies the postero-median fissure is likewise firmly attached to its deep surface. In front of the antero-median furrow of the cord the pia mater is thickened in the form of a longitudinal glistening band, termed the **linea splendens**, which runs along the whole length of the cord, and blends with the filum terminale below. The blood-vessels of the spinal cord lie between the two layers of the pia mater.

The nerves which leave both the brain and cord receive closely-applied

sheaths from the pia mater. These blend with the connective-tissue sheaths of the nerves.

The **ligamentum denticulatum** is a strong fibrous band which stretches out like a wing from the pia mater on either side of the spinal cord, so as to connect the pia mater with the dura mater. The pial or inner attachment of the ligament extends in a continuous line between the anterior and posterior nerve-roots, from the level of the foramen magnum above to the level of the first lumbar vertebra below. Its outer margin is serrated or denticulated, and for the most part free. From twenty to twenty-two denticulations may be recognised. They occur in the intervals between the spinal nerves, and pushing the arachnoid before them, they are attached by their pointed ends to the inner surface of the dura mater. The ligamenta denticulata partially subdivide the wide subarachnoid space in the spinal canal into an anterior and a posterior compartment. The anterior nerve-roots traverse the anterior compartment, whilst the posterior nerve-roots traverse the posterior compartment. Further, the posterior compartment is imperfectly subdivided into a right and a left lateral part by the septum posticum.

By means of the ligamenta denticulata the spinal cord is suspended in the middle of the tube of dura mater.

THE SPINAL NERVES, THE CRANIAL NERVES, AND THE SYMPATHETIC NERVOUS SYSTEM.

By A. M. Paterson.

THE SPINAL NERVES.

The **spinal nerves** are arranged in pairs, of which there are usually thirty-one. Each nerve arises by two roots from the spinal cord, and, after leaving the spinal canal through the inter-vertebral foramen, is distributed to the trunk and limbs by means of a series of branches in a manner to be described below.

The spinal nerves are designated **cervical, thoracic, lumbar, sacral,** and **coccygeal,** in relation to the vertebræ between which they emerge from the spinal canal. Each nerve appears below the corresponding vertebra, except the first of the cervical series, which passes out of the spinal canal between the occipital bone and the atlas. There are thus *eight* cervical nerves (the last appearing between the seventh cervical and first thoracic vertebræ); there are *twelve* thoracic, *five* lumbar, *five* sacral, and *one* coccygeal nerve, all appearing below the corresponding vertebræ.

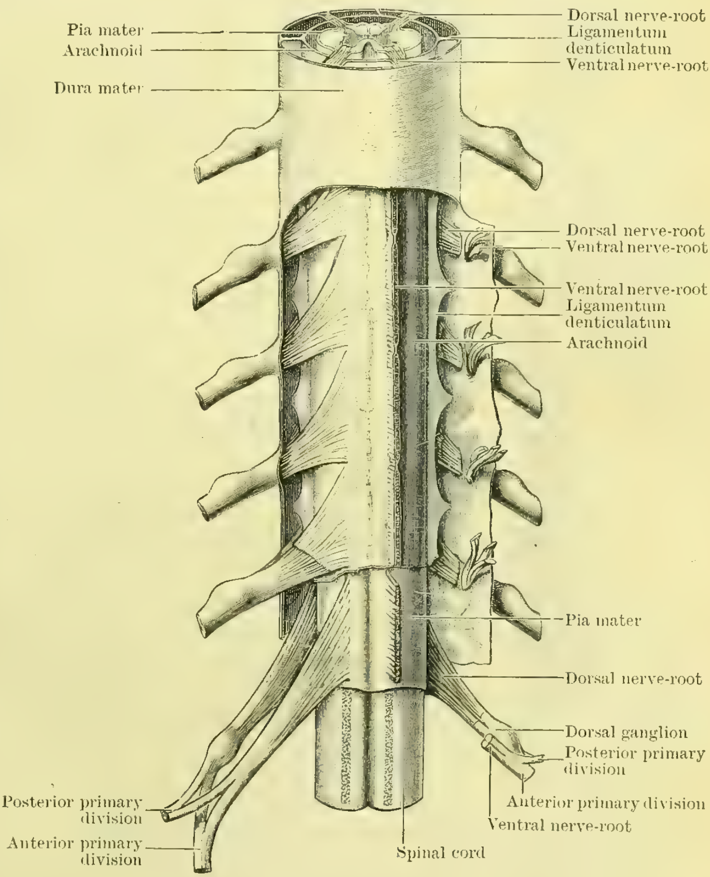


Fig. 419.—Scheme of the Arrangement of the Membranes of the Spinal Cord and the Roots of the Spinal Nerves.

The thirty-first nerve is occasionally absent; and there are sometimes one or two additional pairs of minute filaments below the thirty-first, which, however, do not emerge from the spinal canal. These are rudimentary caudal nerves.

The size of the spinal nerves varies extremely. The largest are those which take part in the formation of the great nerve trunks for the supply of the limbs (lower cervical and first thoracic, and lower lumbar and upper sacral nerves); and of these the nerves destined for the lower limbs are the larger. The coccygeal nerve is the smallest of the

spinal nerves; the thoracic nerves (except the first) are much more slender than the limb nerves; and the cervical nerves diminish in size from below upwards.

Origin of the Spinal Nerves.—Each spinal nerve is attached to the spinal cord by **two roots**, called respectively **dorsal** (posterior), and **ventral** (anterior).

The **dorsal root** is larger than the ventral root; it contains a larger number of rootlets, and the individual rootlets are of larger size than in the ventral root. It has a vertical linear attachment to the postero-lateral sulcus of the spinal cord. The rootlets of contiguous dorsal roots are in close relation, and, in some instances, overlap. The dorsal root separates as it passes away from the cord into two bundles, both of which become connected with the inner end of a **spinal ganglion**. From the outer end of this ganglion the dorsal root proceeds to its junction with the ventral root in the inter-vertebral foramen.

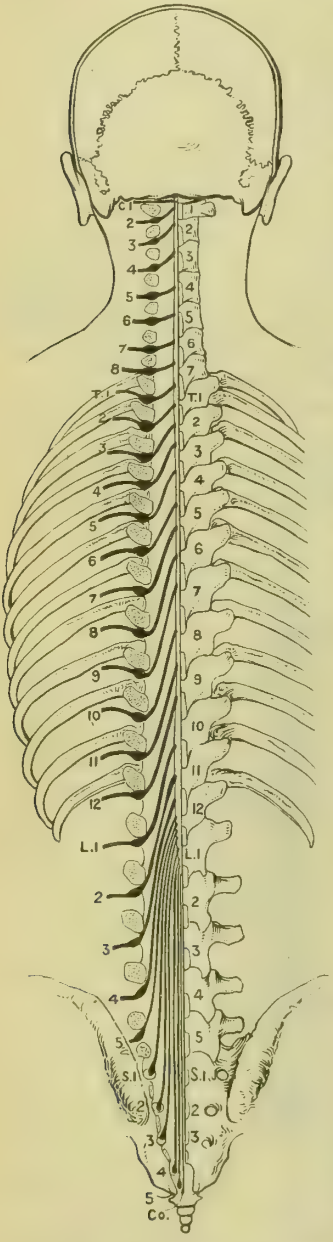


Fig. 420.—Diagrammatic Representation of the Roots and Ganglia of the Spinal Nerves, showing their position in relation to the spinal column. The nerves are shown as thick black lines on the left side.

The **spinal ganglia** are found on the dorsal roots of all the spinal nerves. (In the case of the first cervical (sub-occipital) nerve, the spinal ganglion may be rudimentary or absent; and the dorsal root itself may be wanting, or derived from the spinal accessory nerve.) They occupy the inter-vertebral foramina, except in the case of the sacral and coccygeal ganglia, which lie *within* the vertebral canal, and the first and second cervical nerves, the ganglia of which lie upon the neural arches of the atlas and axis respectively. With the exception of the coccygeal ganglion they are outside the cavity of the dura mater, but are invested by the membrane. The ganglia are of ovoid form, bifurcated in some cases at their inner ends. They consist of unipolar nerve-cells, whose processes, after a very short course, divide into central and peripheral fibres: the central fibres form the portion of the root entering the spinal cord; the peripheral fibres are continued in an outward direction from the ganglion into the spinal nerve.

Accessory spinal ganglia (ganglia aberrantia).—Between the spinal ganglion and the spinal cord small collections of cells are occasionally found on the dorsal roots, either as scattered cells or distinct ganglia. They are most frequently met with on the dorsal roots of the lumbar and sacral nerves.

The **ventral root** is smaller than the dorsal root. It arises from the anterior surface of the spinal cord (*anterior root zone*) by means of scattered bundles of nerve fibres, which occupy a greater horizontal area and are more irregular in their arrangement than the fascicles of the dorsal root. It possesses no ganglion in its course. The rootlets sometimes overlap, and are not unfrequently connected with neighbouring rootlets above and below.

The dorsal and ventral roots, from their attachment to the spinal cord, proceed outwards in the spinal canal towards the intervertebral foramina, where they unite to form the spinal nerve. The direction of the roots of the first two nerves is upwards and outwards; the roots of the remaining nerves course obliquely downwards and outwards, the obliquity gradually increasing until, in the case of the lower lumbar, the sacral and coccygeal nerve-roots, their course is vertically down-

wards in the spinal canal. The collection of nerve-roots which occupies the lower part of the canal below the first lumbar vertebra, and comprises all the nerve-roots below those of the first lumbar nerve, is designated the **cauda equina.** They arise from the lumbar enlargement and conus medullaris, and surround the filum terminale of the spinal cord.

Within the spinal canal the nerve-roots are in relation with the meninges of the cord, and are separated from one another by the ligamentum denticulatum, and, in the neck, by the spinal part of the spinal accessory nerve. Each receives a covering of pia mater, continuous with the neurilemma; the arachnoid invests each root as far as the point where it meets with the dura mater; the two roots, after piercing the dura mater separately, are enclosed by it in a single tubular sheath, in which is included the spinal ganglion of the dorsal root.

Divisions of a Spinal Nerve.—The spinal nerve thus formed lies in the intervertebral foramen, except in the case of the first two cervical and the sacral and coccygeal nerves. It immediately divides into two primary divisions, named respectively the **posterior** and **anterior primary divisions.** Just before its division each nerve gives off a minute **recurrent branch,** which re-enters the vertebral canal after effecting a junction with a branch from the sympathetic cord, and is distributed to the spinal cord and its membranes.

The posterior and anterior primary divisions of the spinal nerve are responsible for the innervation of the skeletal muscles and the skin covering the trunk and limbs.

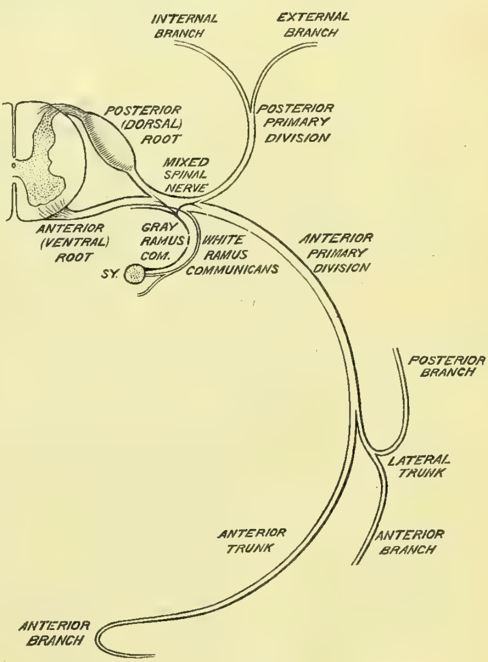


Fig. 421.—Scheme of the Distribution of a Typical Spinal Nerve.

In relation to certain spinal nerves, a series of much smaller branches exist which are connected with the sympathetic system (Fig. 421, *SY*), in a way to be described later. These constitute the **white rami communicantes,** and may be termed the **visceral divisions** of the spinal nerves. They are derived from the anterior primary divisions of the nerves, and receive their fibres mainly from the ventral roots, though, at least in the case of certain nerves, from the dorsal roots as well. These nerves are directed inwards from the intervertebral foramen over the vertebral column, and, becoming connected with the sympathetic cord, convey spinal fibres to the organs and tissues in the splanchnic area.

The posterior and anterior primary divisions of the nerves contain fibres from both dorsal and ventral roots. Indeed each root can be seen on removal of its sheath to divide into two portions, of which one portion enters into the formation of the posterior, the other into the formation of the anterior primary division. The posterior primary divisions, with the exception of the first two, are smaller than the anterior primary divisions. They supply in general the skin and muscles of the back. They do not supply muscles of the limbs; although in their cutaneous distribution they are prolonged on to the back of the head, the shoulder, and the buttock. They form two small plexuses, the **posterior cervical** and the **posterior sacral plexuses.** The anterior primary divisions are, with the exception of the first two cervical nerves, much larger than the posterior primary divisions. They supply the sides and fore-parts of the body, the perineum, and the limbs. For the most part they have a complicated arrangement. The thoracic or intercostal nerves alone have a simple mode of distribution; the other nerves give rise to the three great **plexuses—cervical, brachial,** and **lumbo-sacral.**

Distribution of the Spinal Nerves.—The distribution, like the origin of the

posterior and anterior primary divisions of the spinal nerves, presents primarily and essentially a segmental arrangement, masked and in some cases obliterated by developmental changes which have occurred in the parts supplied. In no region can a single nerve be traced to a complete segment. In the trunk between the limbs the nearest approach to a complete girdle is formed by such a nerve as the sixth thoracic nerve. In its cutaneous distribution it forms a perfect belt, the nerve by its posterior and anterior primary divisions supplying a distinctly segmental area from the middle line of the trunk behind to the sternum in front. Its muscular distribution, also, is almost perfectly segmental. The anterior primary division supplies, unaided, the intercostal muscles of the segment in which it lies. The posterior primary division supplies muscles in the back, not, however, in a strictly segmental manner, on account of the fact that the segmental myotomes have fused together in the back to give rise to complex longitudinal muscles, which are together supplied by the series of muscular branches derived from these posterior primary divisions. In other regions greater changes cause more marked deviations from a simple segmental type of distribution and give rise to the various plexuses, by which the trunk, and more particularly the limbs, are innervated.

POSTERIOR PRIMARY DIVISIONS OF THE SPINAL NERVES.

The posterior primary divisions of the spinal nerves are distributed generally to the skin of the back of the trunk, the back of the head, the shoulder and the buttock, and to the longitudinal muscles of the back, but not to the muscles of the limbs.

Each posterior primary division divides as a rule into two parts, an **internal** and an **external trunk** (Fig. 421, p. 567). In the upper half of the body the internal trunks generally supply the cutaneous branches, while the external trunks are purely muscular nerves. In the lower part of the body the opposite is the case: the external trunks provide the cutaneous nerves and the internal trunks are distributed entirely to muscles. The cutaneous branches have a different course in the two cases. In the upper half of the back they course inwards and backwards beneath and among the muscles to within a short distance of the spinous processes of the vertebræ, close to which they become superficial. They then extend outwards in the superficial fascia. In the lower half of the back the cutaneous nerves are directed downwards and outwards among the muscles, and become superficial at a greater distance from the middle line.

CERVICAL NERVES.

First Cervical Nerve (n. suboccipitalis).—It has already been pointed out that the dorsal root of this nerve may be rudimentary, or even absent altogether. Its posterior primary division is larger than the anterior primary division; it does not divide into internal or external branches, and does not supply directly any cutaneous branch.

Passing backwards in the space between the occipital bone and the posterior arch of the atlas, the nerve occupies the suboccipital triangle, and is placed below and behind the vertebral artery under cover of the complexus muscle. It supplies the following branches:—

(*a*) **Muscular branches** to the complexus, recti capitis postici, major and minor, and obliqui, superior and inferior.

(*c*) A **communicating branch** descends to join the second cervical nerve.

The communicating branch may arise in common with the nerve to the obliquus inferior, and reach the second cervical nerve by piercing or passing over or beneath the obliquus inferior. Or it may accompany the nerve to the complexus, and communicate with the great occipital nerve, after piercing that muscle.

Second Cervical Nerve.—The posterior primary division of this nerve is larger than the corresponding anterior primary division. It passes backwards in the interval between the atlas and axis, and below the obliquus inferior muscle.

The semispinalis colli is on its inner side and the complexus covers it. In this situation the nerve gives off several small muscular and communicating branches.

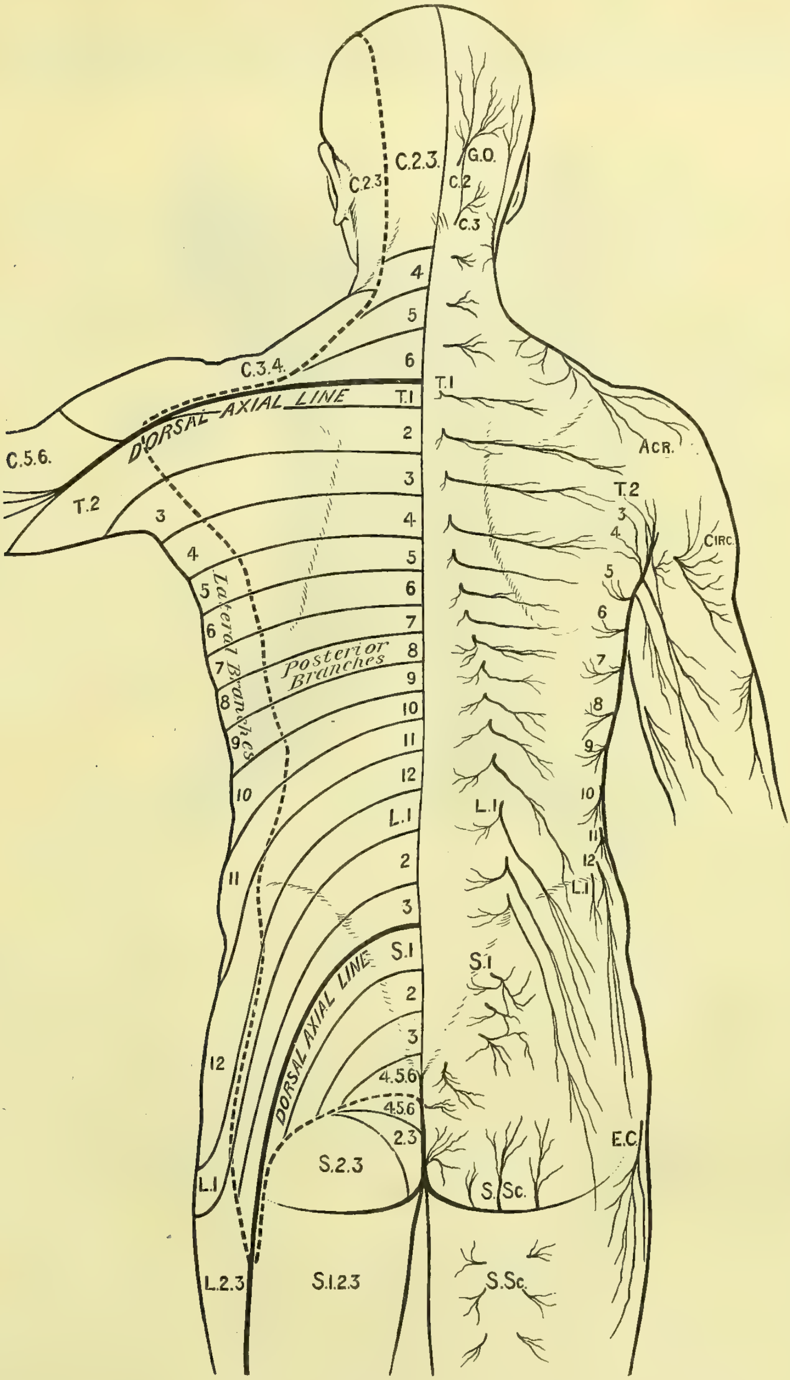


FIG. 422.—THE DISTRIBUTION OF CUTANEOUS NERVES ON THE BACK OF THE TRUNK.

On one side the distribution of the several nerves is represented, the letters indicating their nomenclature. G.O (C.2), Great occipital; C.3, Least occipital; T.1, *et seq.*, Posterior primary divisions of thoracic nerves; L.1, *et seq.*, Posterior primary divisions of first three lumbar nerves; S.1, *et seq.*, Posterior primary divisions of sacral nerves; Acr, Acromial branches from cervical plexus; T.2-12, Lateral branches of thoracic nerves; Circ, Cutaneous branches of circumflex nerve; L.1, Iliac branch of ilio-hypogastric nerve; E.C, External cutaneous nerve; S.Sc, Small sciatic nerve.

On the other side a schematic representation is given of the areas supplied by the above nerves, the numerals indicating the spinal origin of the branches of distribution to each area.

The main trunk, after piercing the complexus and trapezius, accompanies the occipital artery to the scalp as the **great occipital nerve** (n. occipitalis major). This is the chief cutaneous nerve for the back part of the scalp. It enters the superficial fascia at the level of the superior curved line of the occipital bone and about an inch from the external occipital protuberance. Ramifying over the surface, it supplies the skin of the scalp as far as the vertex. It *communicates* on

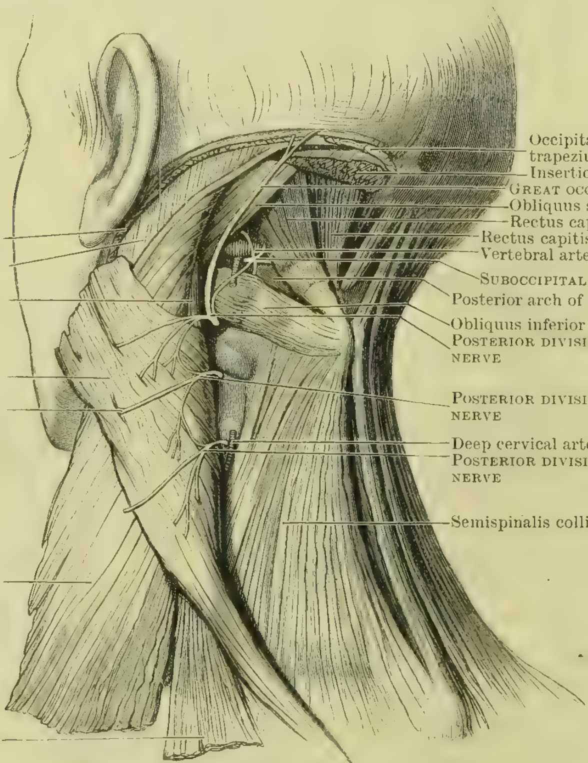


FIG. 423.—THE SUB-OCCIPITAL TRIANGLE.

the scalp with the following nerves: great auricular, small occipital, posterior auricular, and least occipital.

The **muscular branches** of the second cervical nerve are destined for the complexus, obliquus inferior, semispinalis colli, and multifidus spinæ.

Its **communicating branches** form the **posterior cervical plexus**. Descending over the posterior arch of the atlas is a branch from the suboccipital nerve which forms a loop or network with a corresponding branch of the second nerve. From this loop twigs are supplied to the surrounding muscles. A similar loop is formed by a communication between branches of the second and third nerves from which muscles are also supplied. Occasionally a similar loop is formed between branches of the third and fourth nerves.

Third Cervical Nerve.—This is much smaller than the second cervical nerve. Near its origin it forms a loop of communication with the second nerve, and it may give off a similar communicating branch to the fourth nerve. The main trunk divides into internal cutaneous and external muscular branches. The external muscular branch enters contiguous muscles; the internal cutaneous branch passes backwards and inwards, and becomes superficial as the **third** or **least occipital nerve** (n. occipitalis minimus), close to the middle line of the neck. It supplies fine branches to the neck and scalp, and communicates with the great occipital nerve.

The **fourth, fifth, and sixth cervical nerves** are still smaller. Beneath the complexus each divides into external muscular and internal cutaneous branches. The muscular branches supply neighbouring muscles; the cutaneous branches are small nerves, which, passing backwards, become superficial close to the middle line. They supply the skin of the back of the neck. The sixth is the smallest, and its

cutaneous branch is minute, and may be absent altogether. In certain cases the fourth nerve forms, with the third, a loop of communication from which muscles are supplied.

Seventh and Eighth Cervical Nerves.—These are the smallest of the posterior primary divisions of the cervical nerves. They give off ordinarily no cutaneous branches, and end in the deep muscles of the back.

THORACIC NERVES.

The posterior primary division of each thoracic nerve divides into an **internal** and **external branch.** In the case of the upper six thoracic nerves the internal branches are chiefly distributed as cutaneous nerves, while the external branches are wholly muscular in their distribution; in the case of the lower six thoracic nerves the opposite is the case. In all cases the muscular branches serve to innervate the longitudinal muscles of the back. The distribution of the cutaneous branches is different in the upper and lower part of the back. The *upper six* or *seven* thoracic nerves innervate the skin of the scapular region. The **internal cutaneous branches**, after passing backwards from their origin among the dorsal muscles, reach the surface near the spines of the vertebræ and are directed almost horizontally outwards over the vertebral border of the scapula. The first is small; the second is very large and reaches to the acromion process. The rest diminish in size, from above downwards. The **external cutaneous branches** of the *lower five* or *six* thoracic nerves are directed from their origin obliquely downwards and outwards among the parts of the erector spinæ muscle. Becoming cutaneous by piercing the latissimus dorsi at some distance from the middle line they supply the skin of the back in the lower part of the chest and loin, the lowest nerves (eleventh and twelfth) reaching over the iliac crest on to the buttock. The lower nerves often subdivide into two branches before or after their emergence from the latissimus dorsi muscle.

LUMBAR NERVES.

First three Lumbar Nerves.—The posterior primary divisions of the first three lumbar nerves subdivide into internal and external branches, similar in their general arrangement to the lower thoracic nerves. The internal branches are muscular and innervate the deep muscles of the back. The external branches are chiefly cutaneous. They are directed obliquely downwards and outwards among the fibres of the erector spinæ and become superficial by piercing the vertebral aponeurosis, just above the iliac crest and a short distance in front of the posterior iliac spine. They are then directed downwards in the superficial fascia of the buttock and supply a lengthy strip of skin, extending from the middle line above the iliac crest to a point below and behind the great trochanter of the femur.

The **fourth, and fifth lumbar nerves** (like the last two cervical nerves) usually supply only muscular branches to the longitudinal muscles of the back. The fifth nerve sends a communicating branch in many cases to form a loop with the posterior primary division of the first sacral nerve **(posterior sacral plexus).**

SACRAL AND COCCYGEAL NERVES.

The posterior primary divisions of the sacral nerves issue from the posterior sacral foramina. As in the case of the thoracic and lumbar nerves, the upper sacral nerves differ from the lower in their distribution.

The **first three sacral nerves** supply internal muscular branches for the multifidus spinæ, and external cutaneous branches which pierce the fibres of the sacro-sciatic ligament and the gluteus maximus muscle, and supply the skin over the back of the sacrum and contiguous part of the buttock.

The **posterior sacral plexus** consists, like the posterior cervical plexus, of loops or plexiform communications over the back of the sacrum between the posterior primary divisions of the first three sacral nerves, to which are frequently joined branches of the last lumbar nerve and fourth sacral nerve. From these loops branches proceed to

supply the multifidus spinæ muscle; others, piercing the great sacro-sciatic ligament, form secondary loops beneath the gluteus maximus muscle. From the secondary loops, two or more cutaneous branches arise, which, after traversing the muscle, supply the skin of the buttock.

Posterior Sacro-coccygeal Nerve.—The posterior divisions of the fourth and fifth sacral nerves do not divide into internal and external branches. They unite together, and, descending behind the coccyx, receive the minute posterior primary division of the coccygeal nerve. The union of the three nerves constitutes the **posterior sacro-coccygeal nerve**, which, after perforating the sacro-sciatic ligament, is distributed to the skin in the neighbourhood of the coccyx. It supplies no muscles. This nerve is the representative of the **superior caudal trunk** of tailed animals.

Morphology of the Posterior Primary Divisions.

There are several points of morphological interest in relation to the posterior primary divisions of the spinal nerves.

1. **Muscular Distribution.**—In their muscular distribution they are strictly limited to the longitudinal muscles of the back: namely, those associated with the axial skeleton.

2. **Cutaneous Distribution.**—Their cutaneous distribution represents two points of interest.

A. In the first place, while the skin of the back is supplied in a regularly segmental manner by the several nerves, certain of them fail to reach the surface to become cutaneous. The absence of a cutaneous branch from the suboccipital nerve may be due either to the absence of a perfect dorsal root or to its communication with the second nerve. The other nerves which do not usually supply the skin are the seventh and eighth cervical, and the fourth and fifth lumbar nerves. These nerves are placed in the centre of regions in which the upper and lower limbs are developed. They are minute nerves, while the corresponding anterior primary divisions are among the largest of the spinal nerves. Thus opposite the centre of each limb, posteriorly, there is a hiatus in the segmental distribution of the posterior primary divisions of the spinal nerves to the skin of the shoulder and buttock, associated with the formation of the limbs, and the extension into them of the greater part of the nerves of the region. This gap, in the case of the upper limb, commences at the level of the vertebra prominens; in the case of the lower limb it commences opposite the level of the posterior superior iliac spine. It can be continued on to each limb as a hypothetical area (the **dorsal axial line**), which indicates the area of contact (and overlapping) of cutaneous nerves not in strictly numerical sequence. Thus, in the region of the shoulder, the sixth (or fifth) cervical nerve innervates an area of skin adjoining that supplied by the first thoracic nerve; in the region of the buttock the third lumbar nerve supplies an area contiguous with that supplied by the first sacral nerve.

B. The cutaneous branches of the posterior primary divisions of the spinal nerves differ from the muscular branches in their penetration into regions beyond those supplied by their motor roots. The cutaneous branches, in regions where outgrowth or extension from the trunk has occurred, follow this outgrowth; and, in consequence, supply skin covering parts which do not belong to segments represented by the nerves in question. Thus the second and third cervical nerves (great and least occipital) are drawn upwards so as to supply the posterior part of the *scalp*; the upper thoracic nerves are drawn outwards over the *scapular region*; the upper lumbar and sacral nerves supply the skin of the *buttock;* and the sacro-coccygeal nerve forms a rudimentary *caudal nerve.*

3. **Plexuses.**—The plexuses formed by the posterior primary divisions of the upper cervical and upper sacral nerves are the simplest met with in the human body. The posterior cervical plexus is one from which muscular branches are supplied; the posterior sacral plexus is mainly concerned in producing cutaneous offsets. In the case of the **posterior cervical plexus** the loops of communication between the first three or four cervical nerves result in the formation of a series of nerves for the supply of the semi-spinalis, complexus, and other muscles, which bring into contact with these muscles, simultaneously, a considerable area of the spinal cord, and provide a combined and simultaneous innervation for the several parts of each muscle, which has thus an extensive source of energy in the spinal cord. In the case of the **posterior sacral plexus**, the formation of loops between the nerves results in the innervation of any given spot in the cutaneous area supplied from these loops by more than one spinal nerve. As has been said already, the cutaneous nerves, even without the formation of plexuses, overlap in their cutaneous distribution. The formation of a plexus causes a more intimate union of neighbouring spinal nerves, so that stimulation of the surface affects a wider area in the spinal cord than if the nerves passed separately to the surface. While segmentation becomes less obvious, increased co-ordination is effected both of movement and sensation.

ANTERIOR PRIMARY DIVISIONS OF THE SPINAL NERVES.

The anterior primary divisions of the spinal nerves are, with the exception of the first two cervical nerves, much larger than the corresponding posterior primary divisions. Composed of elements of both dorsal and ventral roots, each nerve

emerges from the spinal canal through an intervertebral foramen, and, proceeding outwards, is distributed to the structures on the lateral and anterior aspects of the body, including the limbs. Each nerve is joined near its origin by a **gray ramus communicans** from the sympathetic gangliated cord; and in the case of certain thoracic, lumbar, and sacral nerves, the anterior primary division gives off a delicate bundle of fibres, which forms the **white ramus communicans** of the sympathetic cord. That part of the spinal nerve which is distributed to the body wall and limbs may be termed **somatic**; the small white ramus communicans, innervating the structures in the splanchnic area, may be termed the **visceral** or **splanchnic** part of the spinal nerve. The anterior primary divisions of the spinal nerves are only, in certain cases, distributed in a regular segmental manner. Except in the case of the thoracic nerves, the anterior primary divisions are combined into the three great **plexuses**—cervical, brachial, and lumbosacral, which renders their arrangement and distribution exceedingly complex.

A **thoracic nerve**, such as the fifth or sixth, may be regarded as a type to illustrate the mode of distribution of the anterior

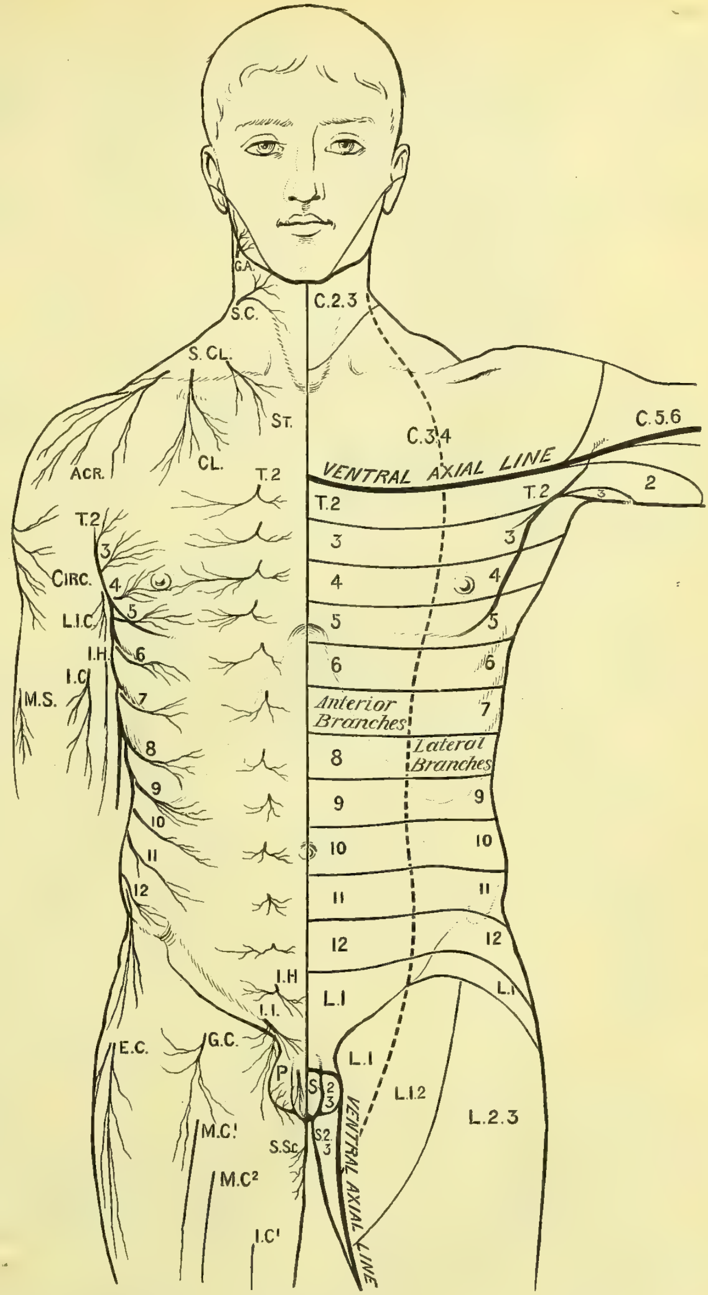


FIG. 424.—THE DISTRIBUTION OF CUTANEOUS NERVES ON THE FRONT OF THE TRUNK.

On one side the distribution of the several nerves is represented, the letters indicating their nomenclature.

G.A, Great auricular nerve; S.C, Superficial cervical nerve; S.CL, Supraclavicular nerves; ACR, Acromial; CL, Clavicular; ST, Sternal; T.2-12, Lateral and anterior branches of thoracic nerves; I.H, Ilio-hypogastric nerve; I.I, Ilio-inguinal nerve; CIRC, Cutaneous branch of circumflex nerve; L.I.C, Lesser internal cutaneous nerve; I.H, Intercosto-humeral; I.C, Internal cutaneous; M.S, Cutaneous branch of musculo-spiral nerve; E.C, External cutaneous nerves; G.C, Genito-crural nerve; M.C$^{1 \cdot 2}$, Middle cutaneous nerves; I.C^1, Branch of internal cutaneous nerve; P, Branches of pudic nerve; S.SC, Branches of small sciatic nerve.

On the other side a schematic representation is given of the areas supplied by the above nerves, the numerals indicating the spinal origin of the branches of distribution to each area.

primary division of a spinal nerve (Fig. 421, p. 567). It occupies an intercostal space; near its origin it possesses *gray* and *white rami communicantes;* it courses through the interval between the intercostal muscles; it supplies branches to these muscles and gives off, when it reaches the side of the chest, a *lateral branch*, which, piercing the external intercostal muscle, is distributed to an area of skin over the lateral part of the trunk, contiguous with a similar area behind, innervated by the cutaneous branches of the posterior primary division of the same nerve. The lateral branch generally subdivides into a smaller *posterior* and a larger *anterior trunk*, as it pierces the muscles clothing the wall of the chest. The anterior primary division of the nerve then pursues its course obliquely forwards to the side of the sternum, where, after piercing the pectoral muscles, it appears superficially as the *anterior terminal cutaneous branch.* This supplies an area of skin continuous with that supplied by the anterior part of the lateral branch of the same nerve. Such a nerve thus supplies, by means of its lateral and anterior branches, an area of skin which (with the area supplied by the cutaneous branch of its posterior primary division) forms a continuous and uninterrupted belt, extending from the middle line behind to the middle line in front. The lateral and anterior branches of the nerve innervate in their course the intercostal and other muscles, to be afterwards mentioned in detail.

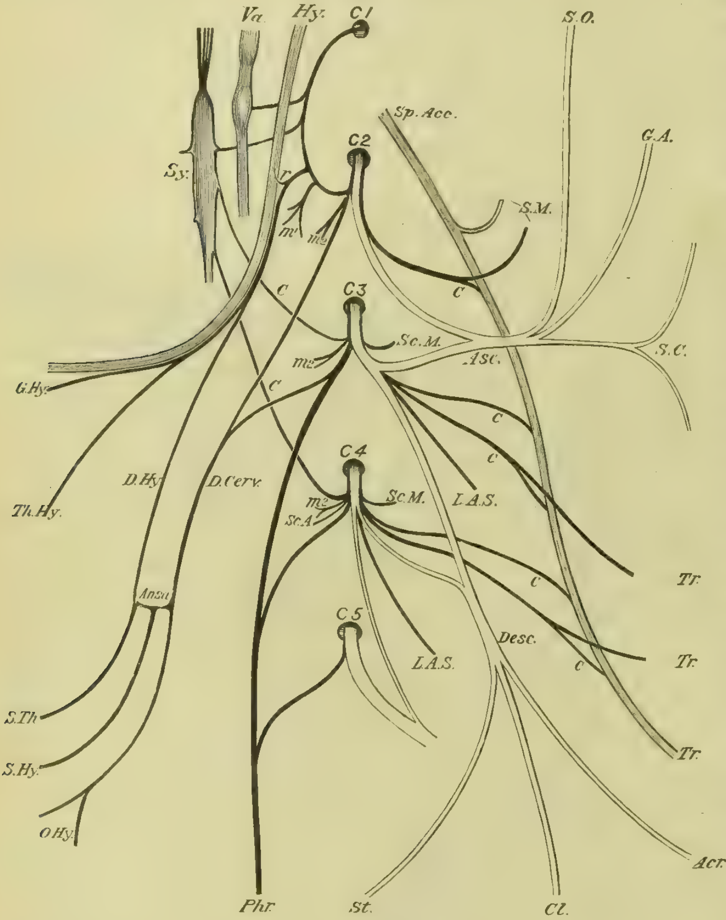


FIG. 425.—THE CERVICAL PLEXUS.

Superficial Division.
- Ascending branches (Asc.)—
  - S.O. Small occipital.
  - G.A. Great auricular.
  - S.C. Superficial cervical.
- Descending (supra-clavicular) branches (Desc.)—
  - Acr. Acromial.
  - Cl. Clavicular.
  - St. Sternal.

Deep Division.
- External branches—
  - Communicating (C.) to spinal accessory nerve (Sp. Acc.).
  - Muscular—
    - S.M. Sterno-mastoid.
    - Tr. Trapezius.
    - L.A.S. Levator anguli scapulæ.
    - Sc.M. Scalenus medius.
- Internal branches—
  - Communicating to
    - Hy. Hypoglossal.
    - Va. Vagus.
    - Sy. Sympathetic ganglion.
    - D.Cerv. Descendens cervicis.
  - Muscular—
    - M[1]. Rectus capitis anticus minor, and lateralis.
    - M[2]. Longus colli, and rectus capitis anticus major.
    - Sc.A. Scalenus anticus.
    - Phr. Phrenic nerve.
    - G.Hy. Nerve to genio-hyoid.
    - Th.Hy. Nerve to thyro-hyoid.
    - D.Hy. Descendens hypoglossi.
    - Ansa. Ansa hypoglossi.
    - S.Th. Nerve to sterno-thyroid.
    - S.Hy. Nerve to sterno-hyoid.
    - O.Hy. Nerves to omo-hyoid.

CERVICAL NERVES.

The anterior primary divisions of the cervical nerves, together with parts of the first and second thoracic nerves, are distributed to the head, neck, and upper extremity. The first four cervical nerves, by means of the **cervical plexus**, innervate the neck; the last four cervical nerves, together with a large part of the first thoracic nerve, through the **brachial plexus** supply the upper limb. The second thoracic nerve may contribute a trunk to this plexus, and always assists in the innervation of the upper limb.

THE CERVICAL PLEXUS.

The anterior primary divisions of the first four cervical nerves are concerned in forming the cervical plexus. Each nerve emerges from the spinal canal behind the vertebral artery. Each is joined on its emergence from the intervertebral foramen, at the side of the spine, by a **gray ramus communicans** from the superior cervical ganglion of the sympathetic. In the neck the nerves are concealed by the sternomastoid muscle; in front lies the rectus capitis anticus major, and behind are the scalenus medius, and (behind the first or suboccipital nerve) the rectus capitis lateralis. The cervical plexus is constituted by the combination of these nerves in an irregular series of loops under cover of the sterno-mastoid muscle.

From these loops the branches of distribution arise, as (*a*) **cutaneous branches** to the head, neck, and shoulder; (*b*) **muscular branches** to the muscles of the neck; and (*c*) **communicating branches** to the vagus, spinal accessory, hypoglossal and sympathetic nerves.

For convenience of description, the nerves derived from the plexus may be classified as follows:—

I. Superficial (cutaneous) Branches—

A. **Ascending Branches** (C. 2 and 3).
- Small occipital,
- Great auricular,
- Superficial cervical.

B. **Descending (supraclavicular) Branches** (C. 3 and 4)—
- Acromial,
- Clavicular,
- Sternal.

II. Deep (muscular and communicating) Branches—

A. **External Branches.**
1. Muscular branches to
   - Sternomastoid (C. 2),
   - Trapezius (C. 3, 4),
   - Levator anguli scapulæ (C. 3, 4),
   - Scaleni (medius and posticus, (C. 3, 4).
2. Communicating branches to
   - Spinal accessory nerve (C. 2, 3, 4).

B. **Internal Branches.**
1. Muscular branches to
   - Prevertebral muscles (C. 1, 2, 3, 4),
   - Infrahyoid muscles (C. 1, 2, 3) (ansa hypoglossi),
   - Diaphragm (C. 3, 4) (phrenic nerve).
2. Communicating branches to
   - Vagus nerve (C. 1, 2),
   - Hypoglossal nerve (C. 1, 2),
   - C. Hypoglossi (C. 2, 3),
   - Sympathetic (C. 1, 2, 3, 4).

The second, third, and fourth cervical nerves are the chief nerves engaged in forming the plexus. The first cervical nerve only enters into the formation of a small part—the internal portion of the deep part of the plexus.

Superficial Cutaneous Branches.—These nerves, six in number, are entirely cutaneous. They radiate from the cervical plexus, and appear in the posterior triangle of the neck at the posterior border of the sterno-mastoid muscle.

The **small occipital nerve** (n. occipitalis minor) is variable in size and is sometimes double. Its origin is from the second and third cervical nerves (more rarely

from the second only). It extends backwards beneath the sterno-mastoid, and then upwards along its posterior border. Piercing the deep fascia near the apex of the posterior triangle, it divides into **auricular, mastoid,** and **occipital branches,** and supplies small **cervical branches** to the upper part of the neck. The auricular branch supplies the skin of the deep surface of the pinna; the mastoid and occipital branches supply the scalp. The nerve communicates on the scalp with the great occipital and great auricular nerves, and with the posterior auricular branch of the facial nerve.

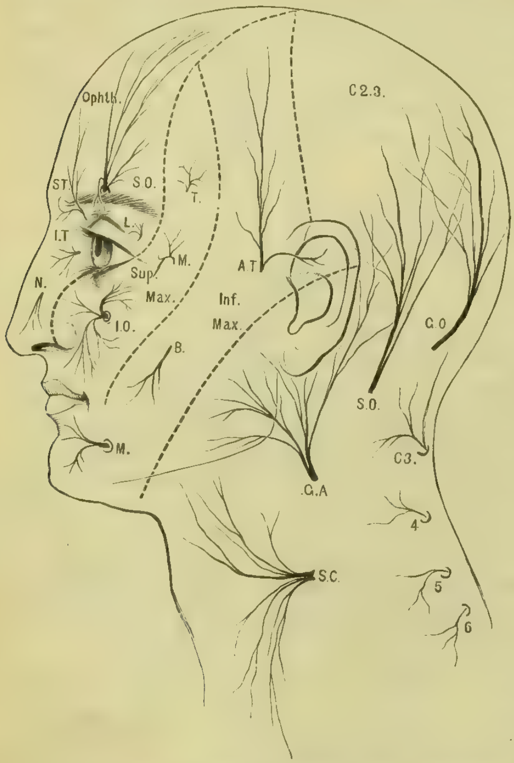


Fig. 426.—Distribution of Cutaneous Nerves to the Head and Neck.

Ophth, Ophthalmic division of the fifth nerve; ST, Supra-trochlear branch; S.O, Supra-orbital branch; I.T, Infra-trochlear branch; L, Lachrymal branch; N, External nasal branch; Sup.Max, Superior maxillary division; T, Temporal branch; M, Malar branch; I.O, Infra-orbital branch; Inf.Max, Inferior maxillary division; A.T, Auriculo-temporal branch; B, Buccal branch; M, Mental branch; C.2, 3, Branches of the second and third cervical nerves; G.O, Great occipital nerve; S.O, Small occipital nerve; G.A, Great auricular nerve; S.C, Superficial cervical nerve; C.3, Least occipital nerve; 4, 5, 6, Posterior primary divisions of 4th, 5th, and 6th cervical nerves.

The **great auricular nerve** (n. auricularis magnus) is the largest of the cutaneous branches. It arises from the second and third cervical nerves (or, more rarely, from the third alone). Winding round the posterior border of the sterno-mastoid muscle, it courses vertically upwards towards the ear. In this course it crosses the sterno-mastoid muscle obliquely and is covered by the platysma myoides. Before arriving at the ear it subdivides into mastoid, auricular, and facial branches. The **mastoid branches** ascend over the mastoid process and supply the skin of the scalp behind the ear, communicating with the small occipital and posterior auricular nerves. The **auricular branches** ascend to the ear and supply the lower part of the pinna on both aspects; they communicate with the same nerves. The **facial branches**, passing over the angle of the jaw and through the substance of the parotid gland, supply the skin of the cheek over the lower part of the masseter muscle and the parotid gland. They communicate with branches of the facial nerve in the parotid gland.

The **superficial cervical nerve** (n. cutaneus colli) arises from the second and third cervical nerves. It winds round the posterior border of the sterno-mastoid muscle, and crosses the muscle to reach the anterior triangle, under cover of the platysma myoides muscle and the external jugular vein. It divides near the anterior edge of the sterno-mastoid muscle into upper and lower branches, which are distributed through the platysma myoides to the skin covering the anterior triangle of the neck. The upper branches communicate freely beneath the platysma myoides with the infra-mandibular branch of the facial nerve.

Descending (supra-clavicular) Branches.—By the union of two roots derived from the third and fourth cervical nerves a considerable trunk is formed, which extends obliquely downwards from under cover of the sterno-mastoid muscle through the lower part of the posterior triangle of the neck. It subdivides into radiating branches—**sternal, clavicular,** and **acromial**—which pierce the deep fascia of the neck above the clavicle, and are distributed to the skin of the lower part of the side of the neck, the front of the chest, and the shoulder. The **sternal branches** (rami suprasternales) are the smallest. Passing over the inner end of the clavicle, they supply the skin of the neck and chest as far down as the lower border of the manubrium,

The **clavicular branches** (rr. supra-claviculares) pass over the middle third of the clavicle, beneath the platysma, and can be traced as low as the nipple. The **acromial branches** (rr. supra-acromiales) pass over or through the insertion of the trapezius muscle, and over the outer third of the clavicle, to the shoulder, where they supply the skin as far down as the lower third of the deltoid muscle.

Deep Branches.—The deep branches of the cervical plexus are naturally separated into an **external** and an **internal set** by their relation to the sterno-mastoid

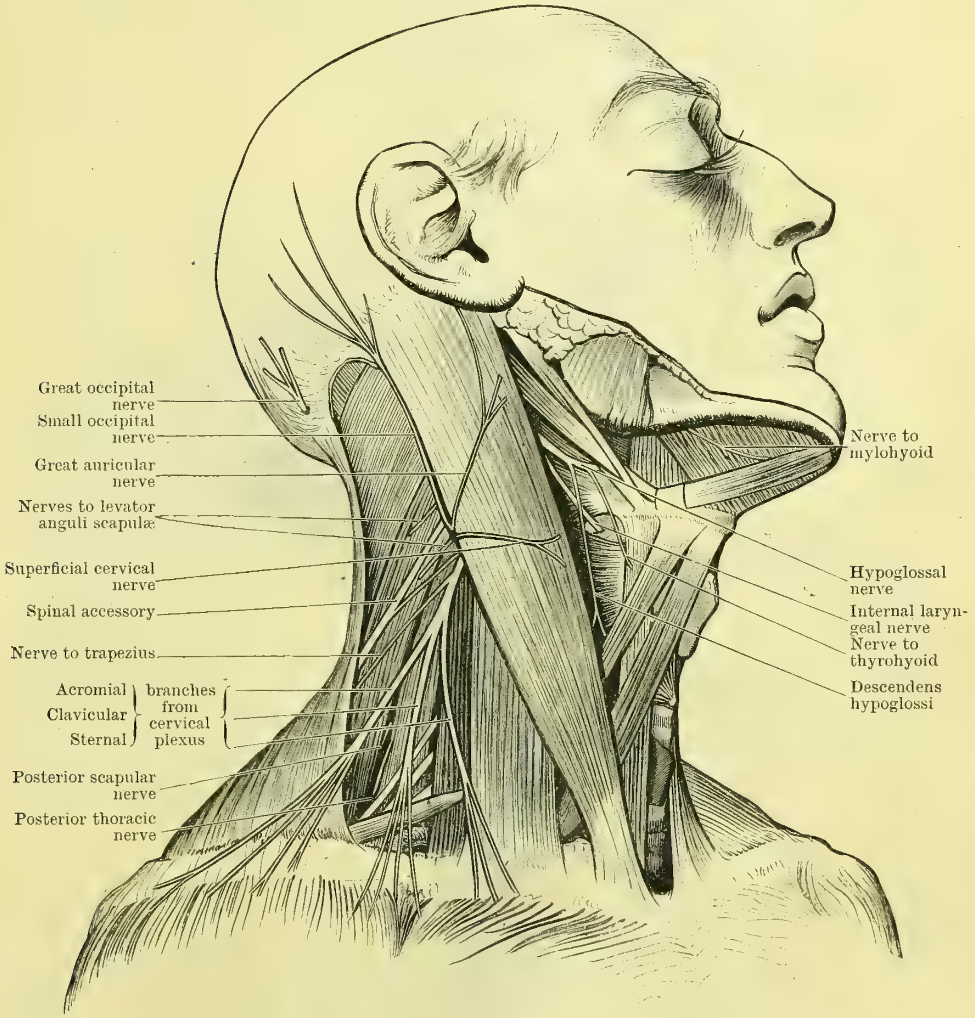


FIG. 427.—THE TRIANGLES OF THE NECK (Nerves).

muscle. Beneath the muscle, the external branches are directed outwards towards the posterior triangle, the internal branches inwards towards the anterior triangle.

The **external branches** consist of muscular and communicating nerves, which for the most part occupy the posterior triangle.

The **muscular branches** are the following: (1) To the *sterno-mastoid*, from the second cervical nerve. This enters the muscle on its deep surface and communicates with the spinal accessory nerve. (2) To the *trapezius*, from the third and fourth cervical nerves. These nerves cross the posterior triangle and end in the trapezius, after having communicated with the spinal accessory nerve, in the posterior triangle, and beneath the muscle. (3) To the *levator anguli scapulæ*, from the third and fourth cervical nerves. Two independent branches enter the outer surface of the muscle in the posterior triangle. (4) To the *scaleni* (medius and posticus), from the third and fourth cervical nerves.

The **communicating branches**, already mentioned, are three in number. They

join the spinal accessory nerve in three situations:—(*a*) A branch from the second cervical nerve to the sterno-mastoid joins the spinal accessory nerve *beneath that muscle.* (*b*) Branches to the trapezius from the third and fourth nerves are connected with the spinal accessory nerve *in the posterior triangle.* (*c*) Branches from the same nerves join the spinal accessory nerve *beneath the trapezius muscle.*

The **internal branches** of the plexus also comprise muscular and communicating branches. The first cervical nerve assists in the formation of this series of

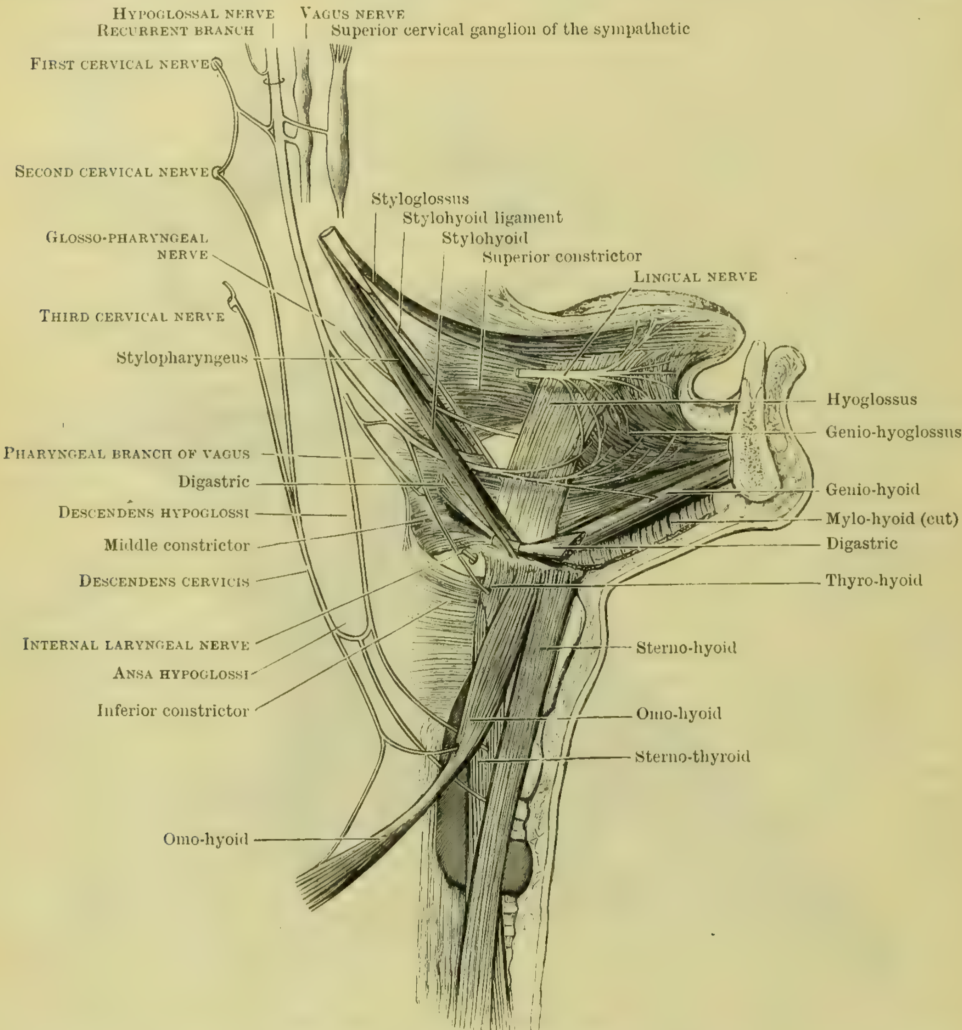


Fig. 428.—The Muscles of the Hyoid Bone and Styloid Process, and the Extrinsic Muscles of the Tongue, with their Nerves.

nerves, forming a slender loop with part of the second nerve in front of the transverse process of the atlas.

Communicating Branches. (*a*) *With the sympathetic.*—Gray rami communicantes pass to each of the first four cervical nerves, near their origins, from the superior cervical ganglion or from the cord below the ganglion. (*b*) *With the pneumogastric nerve.*—The ganglion of the trunk of the pneumogastric nerve may be connected by a slender nerve with the loop between the first two cervical nerves. This communication is not constant. (*c*) *With the hypoglossal.*—An important communication occurs between the hypoglossal nerve and the loop between the first and second cervical nerves (Fig. 428). A trunk from the last-named nerves joins the hypoglossal just beyond its exit from the skull. One fine branch from this trunk passes upwards along the hypoglossal nerve towards the skull (*meningeal branch*).

The main part of the trunk accompanies the hypoglossal and separates from it successively in three nerves—the **descendens hypoglossi**, and the **nerves to the thyro-hyoid** and **genio-hyoid muscles**. The portion of the nerve which remains accompanies the hypoglossal to the muscles of the tongue. It is probable that no part of the hypoglossal nerve itself is concerned in the formation of these three branches. The descending branch of the hypoglossal (r. descendens hypoglossi) descends in front of the common carotid artery, and is joined in the anterior triangle of the neck by the descending cervical nerve, to form the ansa hypoglossi, from which the infra-hyoid muscles are innervated. (The descending branch of the hypoglossal, in some cases, arises from the pneumogastric nerve.)

Muscular Branches. — The muscles supplied by the internal branches of the plexus are the prevertebral muscles, the genio-hyoid and infra-hyoid muscles, and the diaphragm.

(*a*) **Prevertebral Muscles.**—1. From the loop between the first and second cervical nerves a small branch arises, for the supply of the rectus capitis lateralis and the recti capitis antici (major and minor). 2. From the second, third, and fourth nerves small branches supply the intertransversales, longus colli, and rectus capitis anticus major. 3. From the fourth nerve a branch arises for the upper part of the scalenus anticus.

(*b*) **Genio-hyoid and Infra-hyoid Muscles.**—The **descending cervical nerve** (n. cervicalis descendens) is formed in front of the internal jugular vein by the union of two slender trunks from the second and third cervical nerves. It forms a loop of communication in front of the carotid sheath with the descending branch of the hypoglossal nerve (derived ultimately from the first two cervical nerves). This loop of communication is called the **ansa hypoglossi**. It is often plexiform; and from it branches are given to the sterno-hyoid, sterno-thyroid, and omo-hyoid muscles. The nerve to the sterno-hyoid muscle is often continued behind the sternum, to join in the thorax with the phrenic nerve or the cardiac plexus.

The thyro-hyoid muscle and the genio-hyoid muscle are supplied by branches of the hypoglossal nerve, which are traceable back to the communication between the hypoglossal and the first two cervical nerves.

The anterior muscles in immediate relation to the middle line of the neck, between the chin and the sternum, are thus continuously supplied by the first three cervical nerves. The hypoglossal is the nerve of the muscles of the tongue, and it is not certain that it contributes any fibres to the above-named muscles.

(*c*) **Diaphragm.**—The phrenic nerve supplies the diaphragm.

Phrenic Nerve.

The **phrenic nerve** (n. phrenicus) is derived mainly from the fourth cervical nerve, reinforced by roots from the third (either directly or through the nerve to the sterno-hyoid) and fifth (either directly or through the nerve to the subclavius muscle). It passes downwards in the neck upon the scalenus anticus muscle; at the apex of the thorax it passes between the subclavian artery and vein, and traverses the mediastinum to reach the diaphragm, lying in the middle mediastinum between the pericardium and pleura, and in front of the root of the lung. In its course it presents certain differences on the two sides. In the neck, on the left side, it crosses the first part of the subclavian artery; on the right side it crosses the second part. In the superior mediastinum, *on the left side*, it lies between the left subclavian and carotid arteries, and crosses the pneumogastric nerve and the aortic arch. *On the right side* it accompanies the innominate vein and superior vena cava, and is entirely separate from the pneumogastric nerve. The left nerve is longer than the right, owing to the position of the heart and the left half of the diaphragm. The right nerve sends fibres along the inferior vena cava through the foramen quadratum. Reaching the diaphragm the nerve separates into numerous branches for the supply of the muscle; some enter its thoracic surface (sub-pleural branches), but most of the fibres supply it after piercing the muscle (sub-peritoneal branches).

The **branches of the phrenic nerve** are—1. Muscular (to the diaphragm); 2. pleural; 3. pericardiac; 4. inferior vena caval; 5. capsular; and 6. hepatic.

The branches to the pleura and pericardium arise as the phrenic nerve traverses the mediastinum. The branches to the inferior vena cava, suprarenal capsule, and liver arise after communication of the phrenic nerve with the diaphragmatic plexus of the sympathetic on the abdominal surface of the diaphragm.

Communications of the Phrenic Nerve. — 1. The phrenic nerve may communicate with the nerve to the subclavius muscle. 2. It may communicate with the *ansa hypoglossi*, or a branch from it (the nerve to the sterno-hyoid.) 3. It frequently communicates with the cervical part of the sympathetic. 4. It communicates with the solar plexus by a junction upon the abdominal surface of the diaphragm with the *diaphragmatic plexus* on the inferior phrenic artery, in which a small *diaphragmatic ganglion* is found on the right side. From this junction branches are given off to the inferior vena cava, suprarenal capsule, and hepatic plexus.

Morphology of the Cervical Plexus.

The characteristic feature of the cervical plexus is the combination of parts of adjacent nerves into compound nerve trunks by the formation of series of loops. The result of the formation of these loops is that parts (particularly cutaneous areas) are supplied by branches of more than one spinal nerve.

A. **Cutaneous Distribution.**—By the combinations of the nerves into loops the discrimination of the elements in the upper cervical nerves, corresponding to the lateral and anterior branches of a typical thoracic nerve, is made a matter of some difficulty. The second, third, and fourth nerves, through the cervical plexus, supply an area of skin extending, laterally, from the side of the head to the shoulder; anteriorly, from the face to the level of the nipple. The higher nerves supply the upper region (second and third); the lower nerves supply the lower region (third and fourth). It is not possible to strictly compare the individual nerves with the lateral and anterior branches of a thoracic nerve. A line drawn from the ear to the middle of the clavicle separates, however, a lateral from an anterior cutaneous area; and certain of the cutaneous nerves fall naturally into one of these two categories. The nerves homologous with anterior branches of intercostal nerves are the superficial cervical and the sternal branches of the supra-clavicular series; those homologous with lateral branches are the small occipital and acromial branches. The great auricular and clavicular branches are mixed nerves, comprising elements belonging to both sets.

B. **Muscular Distribution.**—The nerves from the cervical plexus, supplying muscles, are simpler in their arrangement. They are not generally in the form of loops, and they are easily separated into lateral and anterior series. The lateral nerves comprise the branches to the rectus capitis lateralis, sterno-mastoid, trapezius, levator anguli scapulæ. The nerves in the anterior series are those to the recti antici, the hyoid muscles, and the diaphragm.

It is noteworthy that the median muscles—genio-hyoid, thyro-hyoid, sterno-hyoid, omo-hyoid, sterno-thyroid, and diaphragm—are continuously supplied by branches from the first five cervical nerves: the higher muscles by the higher nerves; the lower muscles by the lower nerves.

THE BRACHIAL PLEXUS.

The brachial plexus is formed by the anterior primary divisions of the fifth, sixth, seventh, and eighth cervical nerves, along with the greater part of the first thoracic nerve. In some cases a slender branch of the fourth cervical nerve is also engaged; and the second thoracic nerve, in all cases, also contributes to the innervation of the arm, through the intercosto-humeral nerve. In many cases it contributes also directly to the plexus, by an intra-thoracic communication with the first thoracic nerve.

Position of the Plexus.—The nerves forming the brachial plexus appear in the posterior triangle of the neck between the scalenus anticus and scalenus medius muscles; the plexus is formed in close relation to the subclavian and axillary arteries; the nerves emanating from it accompany the artery to the axilla, where they are distributed to the shoulder and upper limb.

Communication with the Sympathetic. — The lower four cervical nerves communicate with the cervical portion of the sympathetic by means of **gray rami communicantes.** Two branches arise from the middle cervical ganglion, and join the anterior primary divisions of the fifth and sixth nerves. Two arising from the inferior cervical ganglion join the seventh and eighth nerves. They reach the nerves either by piercing the prevertebral muscles or by passing round the border of the scalenus anticus muscle.

Composition of the Brachial Plexus.—In an analysis of the brachial plexus four stages may be always seen:—

(1) The undivided nerves.

(2) The separation of the nerves into ventral (anterior) and dorsal (posterior) trunks; and the formation of three primary cords.

(3) The formation of three secondary cords—outer, inner, and posterior.

(4) The origin of the nerves of distribution.

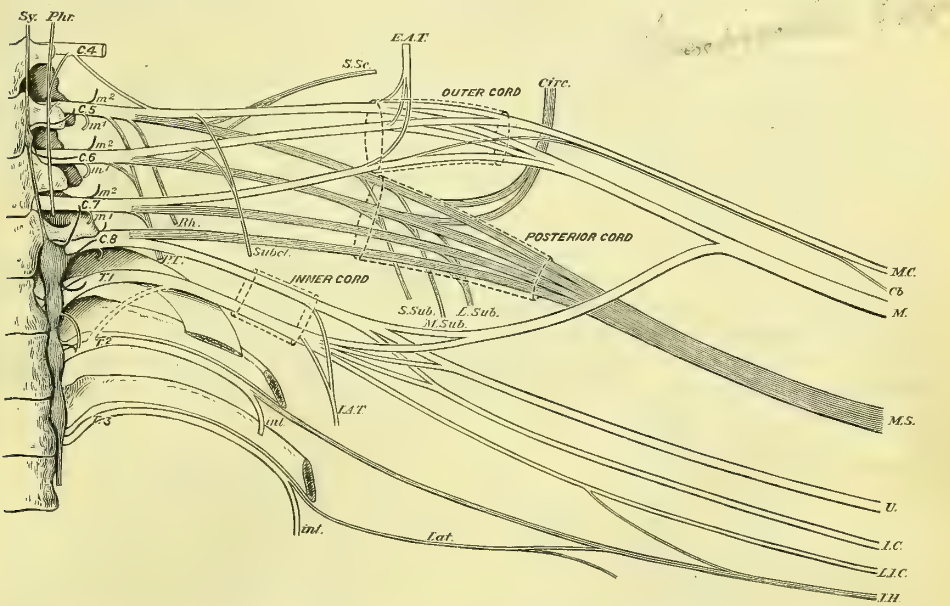


FIG. 429.—THE NERVES OF THE BRACHIAL PLEXUS.

Sy, Sympathetic gangliated cord; Phr, Phrenic nerve; C.4, 5, 6, 7, 8, T.1, 2, 3, Anterior primary divisions of the lower cervical and upper thoracic nerves; M^1, M^2, Muscular branches to axial muscles; P.T, Posterior thoracic nerve; Rh, Nerve to rhomboids (posterior scapular); Subcl, Nerve to subclavius muscle; Int, Intercostal nerves; S.Sc, Suprascapular nerve. The intercostal part of the first thoracic nerve is omitted.

Outer Cord.—E.A.T, External anterior thoracic nerve; M.C, Musculo-cutaneous nerve; Cb, Nerve to coraco-brachialis; M, Median nerve.

Inner Cord.—I.A.T, Internal anterior thoracic nerve; U, Ulnar nerve; I.C, Internal cutaneous nerve; L.I.C, Lesser internal cutaneous nerve.

Posterior Cord.—Circ, Circumflex nerve; M.S, Musculo-spiral nerve; S.Sub, Short subscapular nerve; M.Sub, Lower subscapular nerve; L.Sub, Long subscapular nerve; I.H, Intercosto-humeral nerve; Lat, Lateral branch of third intercostal nerve.

(1) The undivided nerves have only a very short independent course at the side of the neck, after passing between the scalene muscles.

(2) Almost immediately after entering the posterior triangle there are formed three **primary cords**: the first cord is formed by the union of the fifth and sixth nerves together; the second, by the seventh nerve alone; and the third, by the union of the eighth cervical and first thoracic nerves together. While these cords are being formed, a division occurs in each of the last four cervical nerves, into *ventral* (anterior) and *dorsal* (posterior) *trunks;* the first thoracic nerve usually gives rise to no dorsal trunk. The ventral and dorsal trunks of the fifth, sixth, and seventh nerves are nearly equal in size. The dorsal trunk of the eighth cervical nerve is much smaller.

(3) The **secondary cords** of the plexus are formed by combinations of these ventral and dorsal trunks in relation to the axillary artery. They are three in number. The **outer cord** (fasciculus lateralis) is formed by a combination of the ventral trunks of the fifth, sixth, and seventh nerves, and lies on the outer side of the axillary artery. The **inner cord** (fasciculus medialis) is formed by a combination of the ventral trunk of the eighth cervical with the whole of the first thoracic nerve engaged in the formation of the plexus; it lies on the inner side of the axillary artery. The **posterior cord** (fasciculus posterior) is made up of all the

dorsal trunks, from the fifth, sixth, seventh, and eighth cervical nerves, and lies behind the axillary artery. The first thoracic nerve does not usually contribute to the posterior cord.

(4) The **nerves of distribution** for the shoulder and arm are derived from these secondary cords, receiving in this way various contributions from the constituent spinal nerves. *From the outer cord* arise the external anterior thoracic, musculo-cutaneous nerve, and the outer head of the median nerve. *From the inner cord* arise the inner head of the median, the ulnar, internal cutaneous, lesser internal cutaneous, and the internal anterior thoracic nerves. *From the posterior cord* arise the circumflex, three subscapular, and the musculo-spiral nerves.

It is to be remembered that, although derived from a secondary cord formed by a certain set of spinal nerves, any given nerve does not necessarily contain fibres from all the constituent nerves; *e.g.* both the musculo-cutaneous and circumflex nerves, from the outer and posterior cords, are ultimately derived only from the fifth and sixth cervical nerves.

The Branches of the Brachial Plexus.

It is customary to separate artificially the nerves of distribution of the brachial plexus into two sets: (1) supra-clavicular and (2) infra-clavicular.

Supra-clavicular Nerves.—The nerves derived from the plexus above the level of the clavicle are, like the main trunks, divisible into two series; **anterior branches** arising from the front, and **posterior branches** arising from the back of the plexus (Fig. 429, p. 581).

Anterior Branches.

1. Nerves to scalenus anticus and longus colli.
2. Communicating nerve to join the phrenic nerve.
3. Nerve to the subclavius muscle.

Posterior Branches.

1. Nerves to scaleni, medius and posticus.
2. Posterior scapular nerve.
3. Long thoracic nerve.
4. Supra-scapular nerve.

The **muscular twigs** to the scalenus anticus and longus colli arise from the lower four cervical nerves, as they emerge from the intervertebral foramina.

The **communicating nerve to the phrenic** arises usually from the fifth cervical nerve at the outer border of the scalenus anticus. It is sometimes absent, and occasionally an additional root is present from the sixth cervical nerve. In some instances the nerve is replaced by a branch from the nerve to the subclavius, which passes inwards behind the sterno-mastoid muscle to join the phrenic at the inlet of the thorax.

The **nerve to the subclavius** is a slender nerve, which arises from the front of the cord formed by the fifth and sixth cervical nerves. It descends in the posterior triangle of the neck over the third part of the subclavian artery. It often communicates with the phrenic nerve.

The **branches to the scaleni, medius and posticus,** are small trunks which arise from the lower four cervical nerves as they emerge from the intervertebral foramina.

The **posterior scapular nerve** (n. dorsalis scapulæ, nerve to the rhomboids) arises from the back of the fifth cervical nerve, as it emerges from the intervertebral foramen. It appears in the posterior triangle of the neck, after piercing the scalenus medius muscle. It is directed downwards, under cover of the levator anguli scapulæ and rhomboid muscles, and along the vertebral border of the scapula, to be distributed to the levator anguli scapulæ, rhomboideus minor, and rhomboideus major muscles. It occasionally pierces the levator anguli scapulæ.

The **long thoracic nerve** (n. thoracalis longus, external respiratory nerve of Bell) arises by three roots, of which the middle one is usually the largest, from the back of the fifth, sixth, and seventh nerves, as they emerge from the intervertebral foramina. The nerve pierces the scalenus medius in one or two trunks, and, descending along the side of the neck behind the cords of the brachial plexus, it enters the axilla between the upper edge of the serratus magnus and the axillary artery. It continues its downward course over the outer surface of the serratus magnus, to which it is distributed.

There is a more or less definite relation between the roots of this nerve and the parts of the serratus magnus. The first part of the muscle is innervated by the fifth nerve alone ; the second part by the fifth and sixth, or the sixth alone ; the third part by the sixth and seventh, or the seventh nerve alone.

The **suprascapular nerve** (n. suprascapularis) arises from the back of the cord formed by the fifth and sixth cervical nerves in the posterior triangle of the neck. It occupies a position above the main cords of the brachial plexus, and courses downwards and outwards parallel to them towards the superior border of the scapula. It passes through the suprascapular foramen to reach the dorsum of the scapula. After supplying the supraspinatus muscle it winds round the great scapular notch in company with the suprascapular artery and terminates in the infraspinatus muscle. It also supplies articular branches to the back of the shoulder joint.

Infra-clavicular Nerves.—The so-called infra-clavicular branches of the brachial plexus are distributed to the chest, shoulder, and arm. According to their origin they are divisible into two sets—an **anterior set,** derived from the outer and inner cords, and a **posterior set,** derived from the posterior cord. In their distribution the same division is maintained. The anterior nerves of distribution, springing from the outer and inner cords, supply generally the chest and the front of the limb; the posterior nerves, springing from the posterior cord, supply the shoulder and the back of the limb.

Anterior Branches.

Nerves from the outer cord.

External anterior thoracic. Outer head of median.
Musculo-cutaneous.

Nerves from the inner cord.

Internal anterior thoracic. Ulnar.
Inner head of median. Internal cutaneous.
Lesser internal cutaneous.

Posterior Branches.

Nerves from the Posterior Cord.

Circumflex. Musculo-spiral.
Three subscapular.

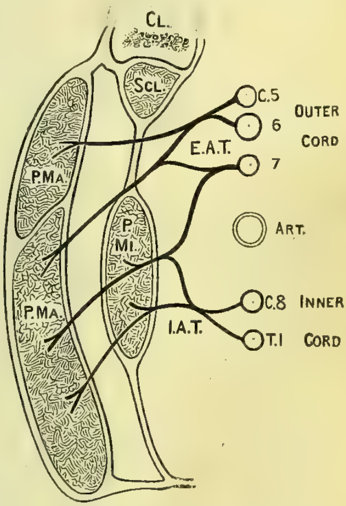


Fig. 430.—Diagram of the Origin and Distribution of the Nerves to the Pectoral Muscles.

E.A.T, External anterior thoracic nerve ; I.A.T, Internal anterior thoracic nerve ; C.5, 6, 7, C.8, T.1, Nerves of the brachial plexus ; Art, Axillary artery ; Cl, Clavicle ; Scl, Subclavius muscle ; P.Mi, Pectoralis minor, joined to subclavius by costo-coracoid membrane ; P.Ma, Pectoralis major.

Anterior Thoracic Nerves.

The **anterior thoracic nerves** (nn. thoracicales anteriores) are two in number, external and internal. The **external anterior thoracic nerve** arises from the outer cord of the brachial plexus by three roots—from the fifth, sixth, and seventh cervical nerves. The **internal anterior thoracic nerve** arises from the inner cord of the plexus, from the eighth cervical and first thoracic nerves. Each courses downwards and forwards on either side of the axillary artery. A loop of communication is formed between them over the artery. They are finally distributed to the pectoralis major and minor muscles (Fig. 430).

The nerves are distributed to the pectoral muscles in the following way :—Two sets of branches from the external anterior thoracic nerve pierce the costo-coracoid membrane. The upper branches supply the *clavicular part* of the pectoralis major ; the lower branches are distributed to the upper fibres of the *sternal portion* of the muscle. The upper branches come from the fifth and sixth cervical nerves ; the lower branches, from the fifth, sixth, and seventh nerves. The *pectoralis minor* is pierced by two sets of nerves—the upper set is derived from the loop of communication between the external and internal anterior thoracic nerves over the axillary artery ; the lower set is derived from the internal anterior thoracic nerve alone. These nerves supply the *pectoralis minor* muscle,

and, after piercing it, supply the *sternal part* of the pectoralis major. The lower nerve, in many cases, sends its branches to the pectoralis major round the lower border of the pectoralis minor, and it may supply on its way the *axillary arches*, if present. These two branches are derived—the upper from the seventh, eighth cervical, and first thoracic

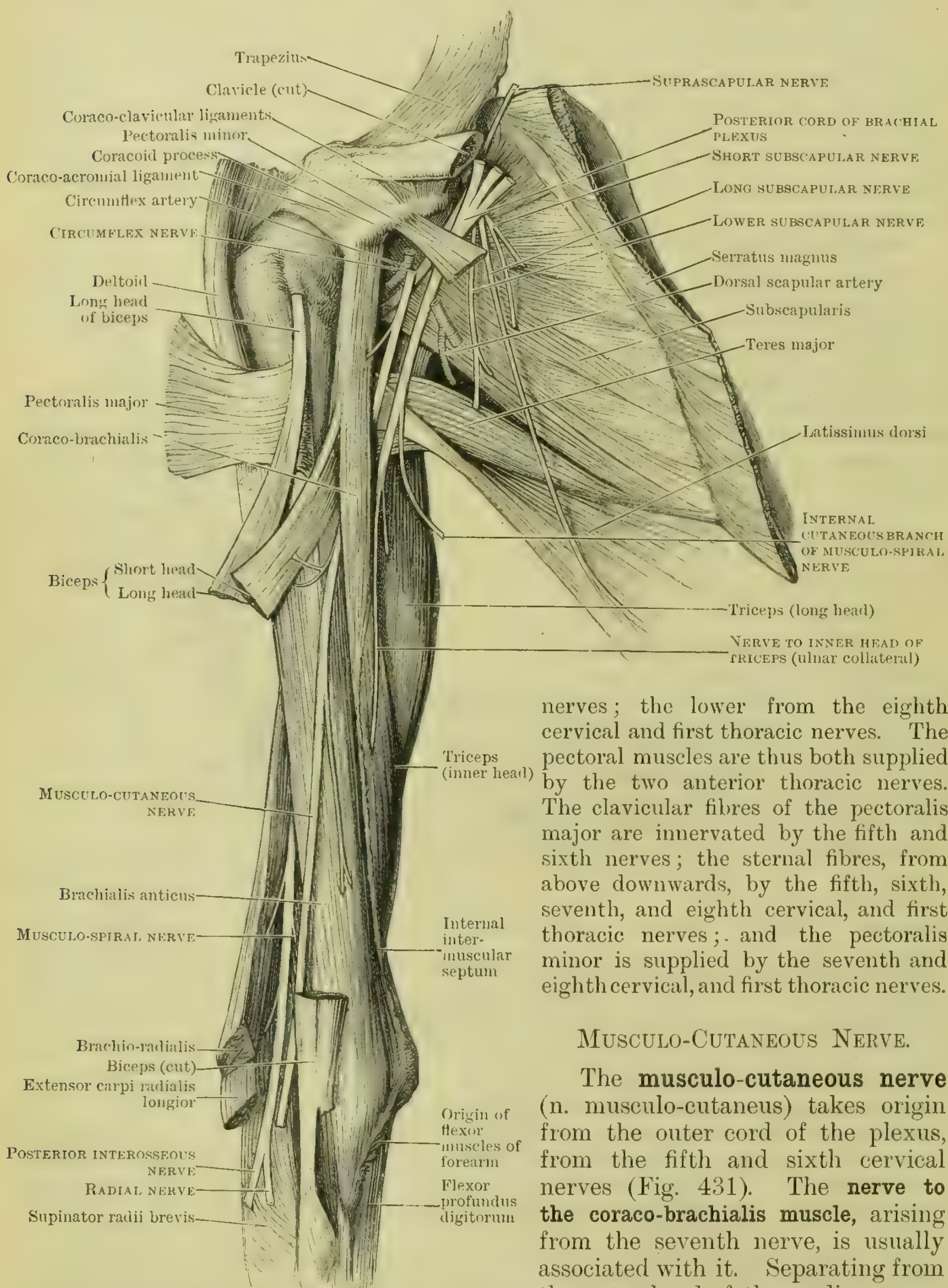


FIG. 431.—THE POSTERIOR WALL OF THE AXILLA AND THE FRONT OF THE ARM (the biceps being divided).

nerves; the lower from the eighth cervical and first thoracic nerves. The pectoral muscles are thus both supplied by the two anterior thoracic nerves. The clavicular fibres of the pectoralis major are innervated by the fifth and sixth nerves; the sternal fibres, from above downwards, by the fifth, sixth, seventh, and eighth cervical, and first thoracic nerves; and the pectoralis minor is supplied by the seventh and eighth cervical, and first thoracic nerves.

MUSCULO-CUTANEOUS NERVE.

The **musculo-cutaneous nerve** (n. musculo-cutaneus) takes origin from the outer cord of the plexus, from the fifth and sixth cervical nerves (Fig. 431). The **nerve to the coraco-brachialis muscle,** arising from the seventh nerve, is usually associated with it. Separating from the outer head of the median nerve, the musculo-cutaneous nerve lies at first between the coraco-brachialis muscle and the axillary artery. It is then directed downwards between the two parts of the coraco-brachialis, and then between the biceps and brachialis anticus muscles, to the bend of the elbow. In its course it may send a branch under the biceps to join the median nerve. It pierces the deep fascia over the front of the

elbow, between the biceps and brachio-radialis, and terminates in cutaneous branches for the supply of the outer side of the forearm.

The branches of the nerve are muscular and cutaneous. The **muscular branches** are supplied to the two heads of the biceps and the brachialis anticus, as the nerve lies between the muscles. The nerve to the coraco-brachialis (usually incorporated with the trunk of the musculo-cutaneous nerve) has an independent origin from the seventh cervical nerve. It is usually double, one branch entering each portion of the muscle. The **cutaneous branches** are anterior and posterior (Fig. 432, p. 586). The **anterior branch** descends along the front of the outer side of the forearm to the wrist, and supplies an area extending inwards to the middle line of the forearm anteriorly, and downwards so as to include the ball of the thumb. It communicates above the wrist with the radial nerve and supplies branches to the radial artery. The **posterior** branch passes backwards and downwards over the extensor muscles and supplies the skin on the outer aspect of the forearm posteriorly in its upper three-fourths, communicating with the cutaneous branches of the musculo-spiral nerve.

In addition to the above branches, the musculo-cutaneous nerve supplies in many cases the following small twigs in the arm: (1) a medullary branch to the humerus; (2) a periosteal branch to the lower end of the humerus on its anterior surface; and (3) a branch to the brachial artery.

Median Nerve.

The **median nerve** (n. medianus) arises by two roots—one from the outer cord, the other from the inner cord of the brachial plexus. The outer head, from the (fifth), sixth, and seventh nerves, descends along the outer side of the axillary artery; the inner head, from the eighth cervical and first thoracic nerves, crosses the end of the axillary artery or the beginning of the brachial artery, to join the other head at the upper part of the arm. Descending along the outer side of the brachial artery, the nerve crosses over it obliquely in the lower half of the arm. In the hollow of the elbow, it lies internal to the brachial artery, beneath the bicipital fascia and the median basilic vein. It passes into the forearm between the two heads of the pronator radii teres muscle, separated from the ulnar artery by the deep origin of that muscle. Extending down the middle of the forearm, between the superficial and deep muscles to the wrist, it enters the palm of the hand on the outer side of the flexor tendons of the fingers beneath the anterior annular ligament. In the hand it spreads out at the lower border of the annular ligament beneath the palmar fascia and superficial palmar arch, and separates into its six terminal branches. In the forearm a small artery accompanies it,—the comes nervi mediani. Above the wrist it is comparatively superficial, lying on the outer side of the flexor tendons and directly beneath the tendon of the palmaris longus.

Communications.—(1) The median nerve, in some cases, receives a communicating branch from the musculo-cutaneous in the arm. (2) It communicates in some cases, in the upper part of the forearm, with the ulnar nerve beneath the flexor muscles. (3) It communicates by means of its cutaneous branches with the ulnar nerve in the palm of the hand.

Branches.—The median nerve usually gives off no branches in the upper arm.

Branches in the Forearm.—(1) **Articular Branches.**—Minute articular filaments are distributed to the front of the elbow joint.

(2) **Muscular Branches.**—Just below the elbow a bundle of nerves arise which is distributed to the following muscles: pronator radii teres, flexor carpi radialis, palmaris longus, flexor sublimis digitorum. Nerves are also generally traceable from this bundle to the upper fibres of the flexor longus pollicis and flexor profundus digitorum. The nerve to the pronator radii teres often arises independently in the hollow of the elbow.

(3) The **anterior interosseous nerve** arises from the back of the median nerve in the forearm, descends in front of the interosseous membrane along with the anterior interosseous artery, passes behind the pronator quadratus muscle, and terminates by supplying articular filaments to the radio-carpal articulation. In its course the nerve supplies muscular branches to the flexor longus pollicis, the outer

half of the flexor profundus digitorum, and the pronator quadratus, minute medullary branches to the radius and ulna, and twigs to the periosteum and interosseous membrane.

(4) **Palmar Cutaneous Branch.**—In the lower third of the forearm a small cutaneous branch arises, which pierces the deep fascia and crosses the anterior annular ligament to reach the palm of the hand. It supplies the skin of the palm and communicates with a similar branch of the ulnar nerve. This branch is not always present.

Branches in the Hand.—In the hand the median nerve gives off its terminal branches. These are muscular and cutaneous.

The main **muscular branch** arises just below the anterior annular ligament and passes outwards to the base of the thenar eminence; entering the ball of the thumb superficially on the inner side, it supplies branches to the abductor pollicis, opponens pollicis, and the superficial head of the flexor brevis pollicis.

The **cutaneous branches** are five in number. Three separate branches supply each side of the thumb and the radial side of the index finger. The two remaining branches subdivide at the cleft between the second and third, and the third and fourth fingers respectively, into branches which supply the adjacent sides of the second and third, and the third and fourth fingers. From the nerves which supply respectively the radial side of the index finger, and the contiguous sides of the index and third fingers, fine muscular branches arise for the two outer lumbrical muscles. The cutaneous branches of the median nerve are placed in the palm between the superficial palmar arch and the flexor tendons. They become superficial at the roots of the fingers between the slips of the palmar fascia, or, in the case of the nerves to the thumb and radial side of the index finger, at the outer edge of the central portion of the palmar fascia. In the fingers they

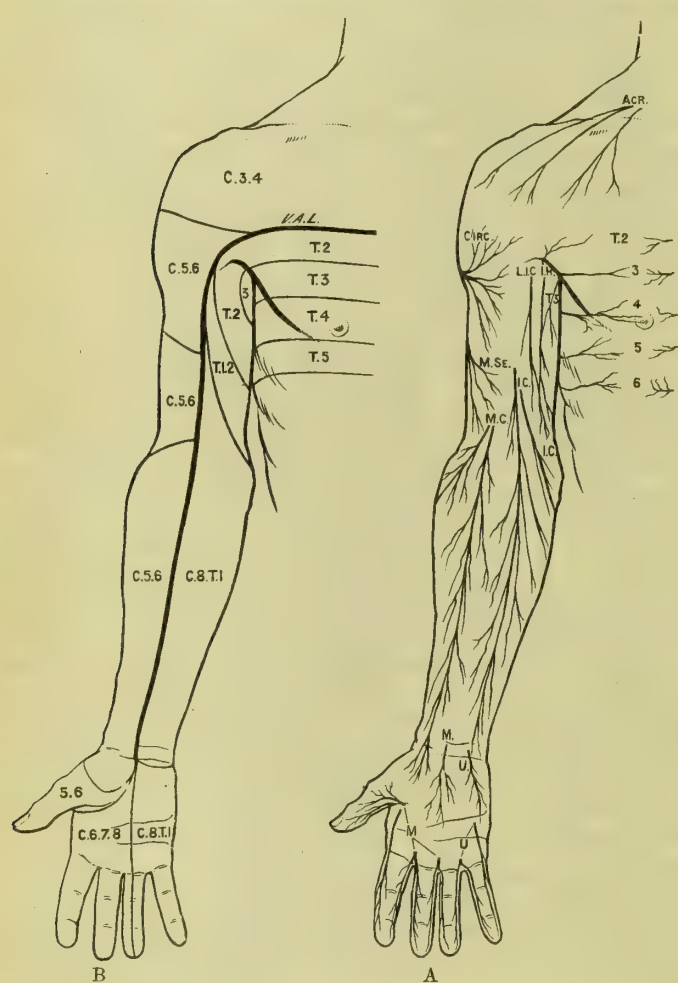


FIG. 432.—THE DISTRIBUTION OF CUTANEOUS NERVES ON THE FRONT OF THE ARM AND HAND.

(A) represents the distribution of the several nerves, the letters indicating their nomenclature. ACR, Acromial branch (cervical plexus); CIRC, Cutaneous branch of circumflex nerve; M.SE, Superior external cutaneous branch of musculo-spiral nerve; M.C, Musculo-cutaneous nerve; M, Median nerve; U, Ulnar nerve; I.C, Internal cutaneous nerve; L.I.C, Lesser internal cutaneous nerve (Wrisberg); I.H, Intercosto-humeral nerve; T.2, 3, 4, 5, 6, Anterior and lateral branches of intercostal nerves.

(B) is a schematic representation of the areas supplied by the above nerves, the lettering indicating the spinal origin of the branches of distribution to each area. V.A.L, Ventral axial line.

are placed superficial to the digital arteries, and are distributed to the sides and front of the fingers. Each nerve supplies one or more dorsal branches, which supply the skin on the dorsal aspect of the terminal phalanx of the thumb and the two distal phalanges of the first two and a half fingers, thus making up for the deficiency of the radial nerve in these situations.

Ulnar Nerve.

The **ulnar nerve** (n. ulnaris) arises from the inner cord of the brachial plexus, from the eighth cervical and first thoracic nerves. In the axilla it lies between the axillary artery and vein, and behind the internal cutaneous nerve; in the upper half of the upper arm it lies on the inner side of the brachial artery in front of the triceps muscle. In the lower half of the arm it is separated from the brachial artery; and passing behind the intermuscular septum, and in front of the inner head of the triceps in company with the inferior profunda artery, it reaches the interval between the internal condyle of the humerus and the olecranon process. It is here protected by an arch of deep fascia stretching between the internal condyle and the olecranon process. It enters the forearm between the humeral and ulnar origins of the flexor carpi ulnaris, and courses downwards between the flexor carpi ulnaris and flexor profundus digitorum. In the lower half of the forearm it becomes comparatively superficial, lying on the inner side of the ulnar artery beneath the tendon of the flexor carpi ulnaris. Just above the anterior annular ligament of the wrist, and external to the pisiform bone, it pierces the deep fascia in company with the artery and passes into the hand over the anterior annular ligament. Reaching the palm it divides beneath the palmaris brevis muscle into its two terminal branches.

Communications. — (1) The ulnar nerve communicates in some cases with the median nerve in the forearm; (2) with the internal cutaneous and sometimes the median nerve by its palmar cutaneous branch; (3) with the cutaneous part of the median nerve in the palm by means of its terminal cutaneous branch; (4) with the radial nerve on the dorsum of the hand by means of its dorsal branch.

Branches.—The ulnar nerve gives off no branches till it reaches the forearm.

In the forearm it gives off articular, muscular, and cutaneous branches. The **articular branch** is distributed to the elbow joint and arises as the nerve passes behind the internal condyle.

The **muscular branches** arise as soon as the nerve enters the forearm. They are distributed to the muscles between which the ulnar nerve lies—the flexor carpi ulnaris and the inner half of the flexor profundus digitorum.

The **cutaneous branches** are two in number, palmar and dorsal.

The **palmar cutaneous branch** is variable in size and position. It pierces the deep fascia in the lower third of the forearm and passes to the hypothenar eminence and palm of the hand, to which it is distributed. It gives branches to the ulnar artery, and communicates often with the internal cutaneous and palmar branch of the median nerve.

The **dorsal cutaneous branch** is much larger (Fig. 433, p. 588). It arises from the ulnar nerve in the middle third of the forearm; and, directed obliquely downwards and backwards beneath the tendon of the flexor carpi ulnaris, it becomes cutaneous on the inner side of the forearm in its lower fourth. It passes on to the back of the hand, and after giving off branches to the skin of the wrist and hand, which communicate with the radial nerve, it terminates in two branches, to supply the little finger and half the ring-finger in the following way:—the inner branch courses along the inner side of the dorsum of the hand and little finger: the outer branch subdivides at the cleft between the ring and little fingers to supply the adjacent sides of these fingers; this branch communicates with the radial nerve. The nerve may supply two and a half fingers on the dorsum of the hand.

In the palm the ulnar nerve supplies a small muscular branch to the palmaris brevis muscle, and then subdivides into its terminal branches, which are named superficial and deep.

The **superficial branch** is purely cutaneous; it passes downwards beneath the palmar fascia, and subdivides into an inner and an outer branch. The inner branch courses along the inner border of the little finger, which it supplies on its palmar aspect. The outer branch becomes superficial at the cleft between the fourth and fifth fingers, between the slips of the palmar fascia, and subdivides into two branches which supply the adjacent sides of these fingers on their palmar aspect. It communicates with the adjacent digital branch of the median nerve.

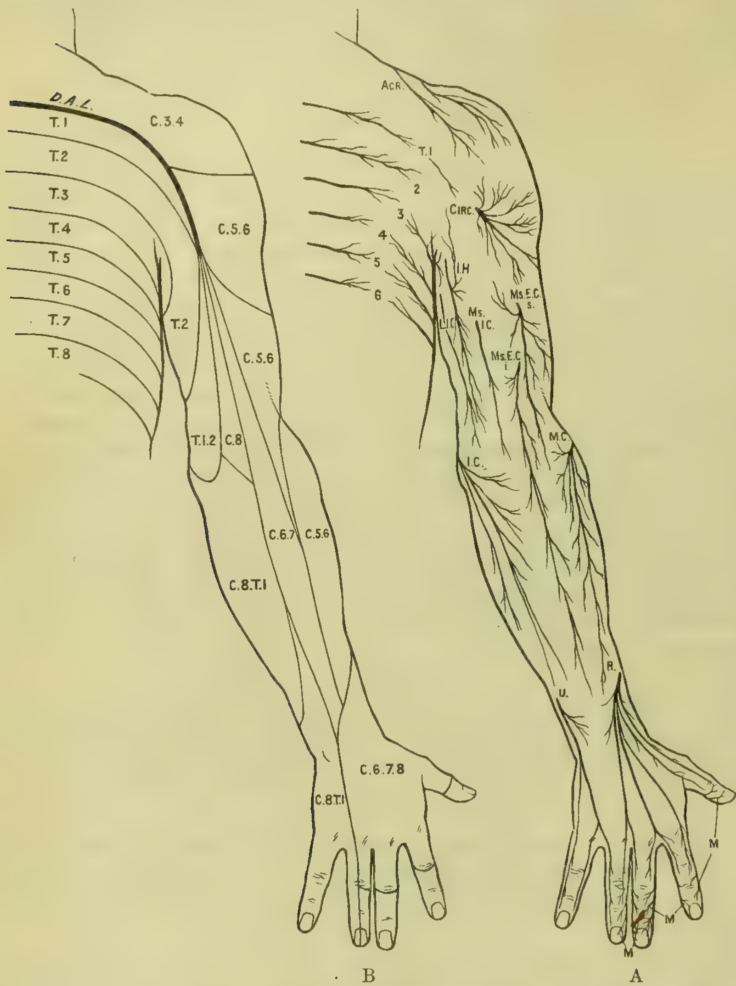


FIG. 433.—THE DISTRIBUTION OF CUTANEOUS NERVES ON THE BACK OF THE ARM AND HAND.

(A) represents the distribution of the several nerves, the letters indicating their nomenclature. ACR, Acromial branches (cervical plexus); CIRC, Cutaneous branch of circumflex nerve; Ms.E.C.s, Ms.E.C.i, Superior and inferior external cutaneous branches of musculo-spiral nerve; M.C, Musculo-cutaneous nerve; R, Radial nerve; M, Branches of median nerve to fingers; U, Ulnar nerve; I.C, Internal cutaneous nerve; Ms.I.C, Internal cutaneous branch of musculo-spiral nerve; L.I.C, Lesser internal cutaneous nerve (Wrisberg); I.H, Intercosto-humeral; T.1, 2, 3, 4, 5, 6, Lateral and posterior branches of upper thoracic nerves.

(B) is a schematic representation of the areas supplied by the above nerves, the lettering indicating the spinal origin of the branches of distribution to each area. D.A.L, Dorsal axial line.

The **deep branch** is purely muscular. It separates from the superficial branch, and passes deeply between the flexor brevis and abductor minimi digiti muscles; it supplies these muscles and the opponens minimi digiti, and, turning outwards along the line of the deep palmar arch and under cover of the deep flexor tendons, it supplies branches to the following muscles: the interossei, two inner (third and fourth) lumbricales (on their deep surfaces), the adductores, obliquus and transversus, and deep part of the flexor brevis pollicis.

INTERNAL CUTANEOUS NERVE.

The **internal cutaneous nerve** (n. cutaneus brachii medialis) arises from the inner cord of the brachial plexus, from the eighth cervical and first thoracic nerves (Figs. 432 and 433). In the axilla and upper half of the arm it lies superficial to the main arteries. It becomes cutaneous by piercing the deep fascia about the middle of the inner side of the upper arm, and, accompanying the basilic vein

through the lower half of the arm, it divides at the front of the elbow into its two terminal branches.

Communication.—The internal cutaneous nerve communicates with the palmar branch of the ulnar nerve in the lower part of the forearm.

Branches.—In the arm, as soon as it becomes superficial, the internal cutaneous nerve gives off a branch which supplies the skin of the lower half of the anterior surface of the arm on its inner side. At the elbow it divides into two terminal branches—anterior and internal, which, crossing over or under the median basilic vein, are distributed to the inner side of the forearm.

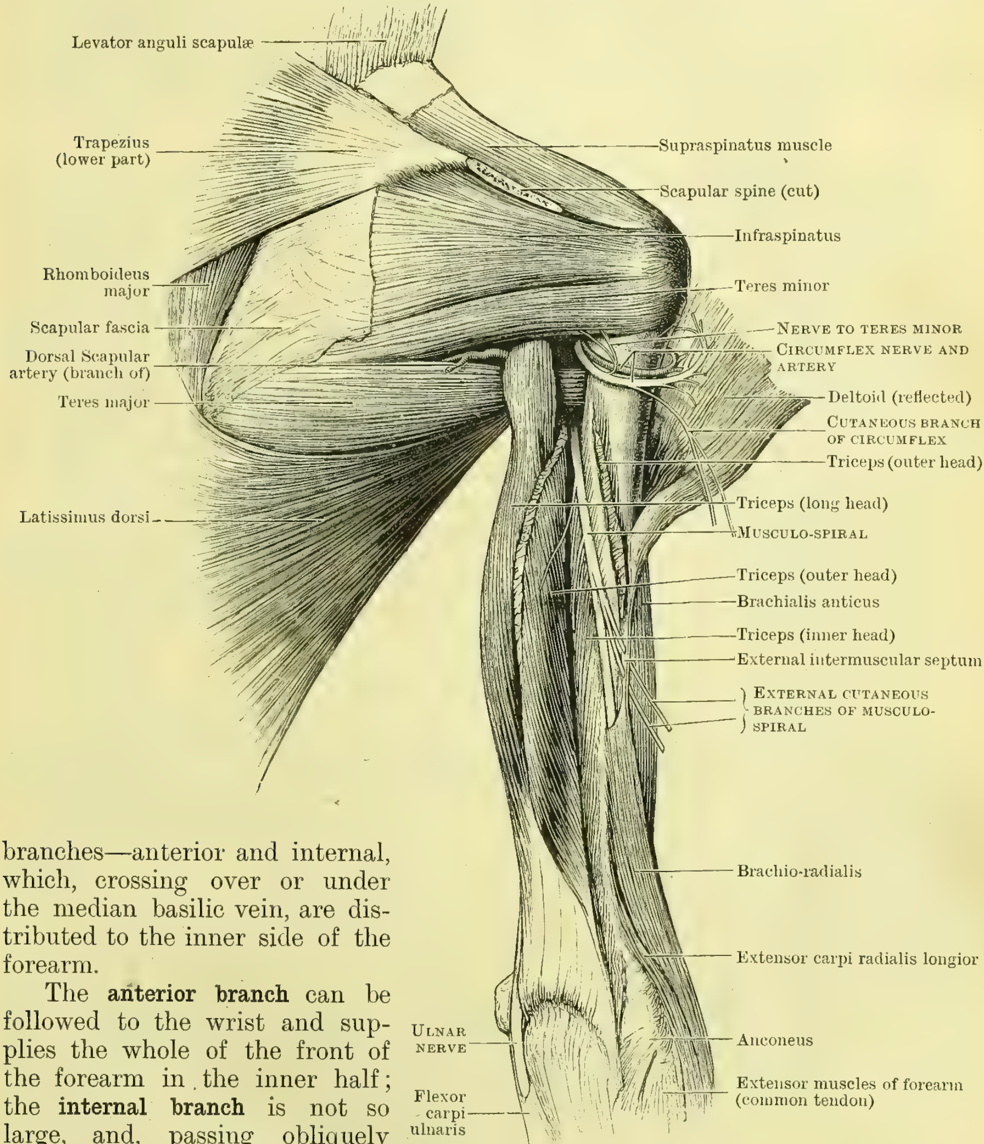


FIG. 434.—DELTOID REGION AND BACK OF ARM.

The **anterior branch** can be followed to the wrist and supplies the whole of the front of the forearm in the inner half; the **internal branch** is not so large, and, passing obliquely backwards and downwards over the origins of the pronator and flexor muscles, it is distributed to the upper two-thirds or three-fourths of the posterior aspect of the forearm on the inner side.

LESSER INTERNAL CUTANEOUS NERVE.

The **lesser internal cutaneous nerve** (n. cutaneus brachii medialis minor) arises from the inner cord of the brachial plexus, and ultimately from the first thoracic nerve (Fig. 429, p. 581). It lies at first between the axillary artery and vein; and after descending over, under, or even, in some cases, through the axillary vein, it

perforates the deep fascia on the inner side of the arm, and is distributed to the skin of the upper half or more of the upper arm in its inner side.

The nerve varies considerably in size. It may be absent, its place being taken by branches of the intercosto-humeral or by branches from the internal cutaneous branch of the musculo-spiral. It generally bears a distinct relation in size to the intercosto-humeral, due to the fact that the size of the latter depends upon the size of the part of the second thoracic nerve connected with the first in the thorax. If an intra-thoracic connexion occurs between the first and second thoracic nerves, the intercosto-humeral may be deprived of a certain number of its fibres, which in that case reach the upper limb through the lesser internal cutaneous nerve. When traced up to the plexus the lesser internal cutaneous is found to have an origin from the back of the cord formed by the eighth cervical and first thoracic nerves, and usually receives fibres from the first thoracic nerve only. In cases where "*axillary arches*" are present they may be supplied by this nerve.

Circumflex Nerve.

The **circumflex nerve** (n. axillaris), at its origin is just below the suprascapular and comes from the same spinal nerves—the fifth and sixth cervical nerves (Fig. 429, p. 581). Extending downwards and outwards behind the axillary artery, it leaves the axilla by passing round the external border of the subscapularis muscle, in company with the posterior circumflex artery, in a quadrilateral space bounded by the humerus, subscapularis, triceps (long head), and teres major. Winding round the surgical neck of the humerus from within outwards, it terminates under the deltoid by supplying that muscle (Fig. 434, p. 589).

Branches.—**Muscular branches** are supplied to the teres minor and deltoid muscles. The nerve to the teres minor enters the outer side of the muscle. It possesses a pseudo-ganglion, a thickening of fibrous tissue, on its trunk.

Articular branches enter the back part of the capsule of the shoulder joint.

A **cutaneous branch** (n. cutaneus brachii lateralis) of considerable size passes obliquely downwards and forwards from beneath the deltoid muscle, becoming superficial at its posterior border. Sometimes the branches pierce the muscle. It supplies the skin over the insertion of the deltoid and the upper half of the arm on the outer side (Fig. 433, p. 588).

Musculo-Spiral Nerve.

The **musculo-spiral** nerve (n. radialis) appears to be the continuation into the upper limb of the posterior cord of the brachial plexus. It usually takes origin from all the nerves which form the posterior cord—the fifth, sixth, seventh, and eighth cervical nerves (Fig. 429, p. 581). In a minority of cases the first thoracic contributes a few fibres, and more frequently the fifth cervical nerve is excluded from it. It extends from the axilla round the back of the humerus to the bend of the elbow, where it ends by dividing into its terminal branches.

In the axilla it lies behind the axillary artery, in front of the subscapularis, teres major, and latissimus dorsi muscles.

In the arm, in the upper third, it lies on the inner side of the humerus behind the brachial artery, and upon the long head of the triceps. In the middle third of the arm it courses obliquely outwards and downwards in the spiral groove of the humerus, along with the superior profunda artery, separating the long, external, and internal heads of the triceps muscle (Fig. 434, p. 589). In the lower third of the arm, piercing the upper part of the intermuscular septum at the outer border of the triceps muscle, it descends to the bend of the elbow in front of the external condyle of the humerus, in the interval between the brachio-radialis and brachialis anticus muscles. Under cover of the former muscle, in the hollow of the elbow, it divides into its two terminal branches, the radial and posterior interosseous nerves.

The **collateral branches** are in three sets, arising (*a*) on the inner side, (*b*) on the back, and (*c*) on the outer side of the humerus (Fig. 435).

Branches arising internal to the humerus.—1. **Internal cutaneous** (n. cutaneus brachii posterior).—This branch, arising in common with one of the following, or independently, pierces the fascia on the inner side of the arm near the axilla. It supplies the skin of the inner side of the arm in the upper third, above and behind the area supplied by the lesser internal cutaneous nerve (Fig. 433, p. 588). This

nerve varies in size, according to the bulk of the lesser internal cutaneous and intercosto-humeral nerves.

2. **Muscular branches** (rr. musculares).—These are in two sets. One series supplies the long head of the triceps muscle near its origin; the other series enters the inner head of the muscle. One of the latter, separating itself from the rest, accompanies the ulnar nerve in the middle third of the arm, and supplies the lower part of the muscle. This is sometimes called the **collateral ulnar nerve.**

Branches arising on the back of the humerus.—**Muscular branches** arise from the nerve in the musculo-spiral groove for the supply of all three heads of the triceps muscle. The branch which enters the inner head of the muscle, besides supplying it, passes through the muscle and behind the external condyle of the humerus, to terminate in the anconeus.

Branches arising at the outer side of the humerus.—1. The **cutaneous branches** (n. cutaneus antibrachii dorsalis) are two in number, superior and inferior. Arising from the musculo-spiral nerve before it pierces the external intermuscular septum, these branches pierce the deep fascia close together on the outer side of the arm in its lower half. Descending over the back of the external condyle, the *superior branch* supplies the skin of the outer side and back of the arm in its lower third, and the back of the forearm in its upper half. The *inferior branch* supplies an area of skin on the back of the forearm in the upper two-thirds internal to the area innervated by the musculo-cutaneous nerve (Fig. 433, p. 588).

2. **Muscular branches.**—The musculo-spiral nerve, as it lies in the interval between the brachialis anticus and brachio-radialis, supplies a small branch to the brachialis anticus (which in some cases is not present) and nerves to the brachio-radialis and extensor carpi radialis longior. It may also provide the nerve to the extensor carpi radialis brevior.

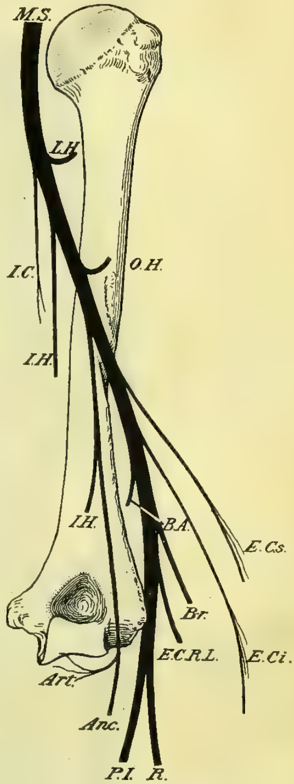


FIG. 435.—DIAGRAMMATIC REPRESENTATION OF THE BRANCHES OF THE MUSCULO-SPIRAL NERVE.

M.S, Musculo-spiral nerve; L.H, Nerve to long head of triceps; I.C, Internal cutaneous branch; I.H, Nerve to inner head of triceps; O.H, Nerve to outer head of triceps; I.H, Second nerve to inner head of triceps; Anc, Nerve to anconeus; Art, Articular branch; E.Cs, Superior external cutaneous branch; E.Ci, Inferior external cutaneous branch; B.A, Nerve to brachialis anticus; Br, Nerve to brachio-radialis; E.C.R.L, Nerve to extensor carpi radialis longior; P.I, Posterior interosseous nerve; R, Radial nerve.

RADIAL NERVE.

The **radial nerve** (r. superficialis) is entirely cutaneous in its distribution. Arising in the hollow of the elbow beneath the brachio-radialis, it courses downwards under cover of that muscle through the upper two-thirds of the arm, and accompanies the radial artery in the middle third of the forearm. It then passes backwards beneath the tendon of the brachio-radialis and pierces the deep fascia in the outer side of the forearm in the lower third. It is distributed to the skin of the back of the wrist, the outer side and the back of the hand, and the back of the thumb and outer two and a half fingers (Fig. 433, p. 588). Its branches communicate on the ball of the thumb with the musculo-cutaneous nerve, and on the back of the hand with the dorsal branch of the ulnar nerve. The digital branches are small, and are five in number. Two pass to the back of the thumb and reach the inter-phalangeal articulation. One supplies the radial side of the index finger as far as the second phalanx. The remaining two branches divide at the clefts between the second and third, and third and fourth fingers respectively, and innervate the adjacent sides of these fingers as far as the second phalanx. The rest of the skin of these digits to the tips is supplied by digital branches of the median nerve.

Posterior Interosseous Nerve.

The **posterior interosseous nerve** (r. profundus, n. interosseus antibrachii dorsalis) is entirely muscular and articular in its distribution, and it arises like the radial beneath the brachio-radialis muscle. Directed obliquely downwards and backwards, it reaches the back of the forearm, after passing round the outer side of the radius, by piercing the fibres of the supinator radii brevis muscle (Fig. 436). On the back of the forearm it is placed in the upper part of its course beneath the superficial extensor muscles, and upon the supinator radii brevis and extensor ossis metacarpi pollicis, along with the posterior interosseous artery. In the lower half of the forearm it passes beneath the extensor longus pollicis, and lies upon the interosseous membrane. At the wrist it passes beneath the extensor tendons on to the back of the carpus, where it terminates in a gangliform enlargement of small size, from which branches pass to the inter-carpal articulations. The posterior interosseous nerve supplies the following branches:—

(1) Terminal **articular branches** to the carpal joints.

(2) **Muscular branches,** in its course through the forearm. Thus on the outer side of the radius it supplies the extensor carpi radialis brevior and the supinator brevis muscle before it enters the fibres of the last-named muscle. After emerging from the supinator brevis it supplies a large bundle of nerves which enter the extensor communis digitorum, extensor minimi digiti, and extensor carpi ulnaris near their origins. Lower down the forearm the nerve gives off branches to the extensor ossis metacarpi pollicis, extensor longus and extensor brevis pollicis, and extensor indicis.

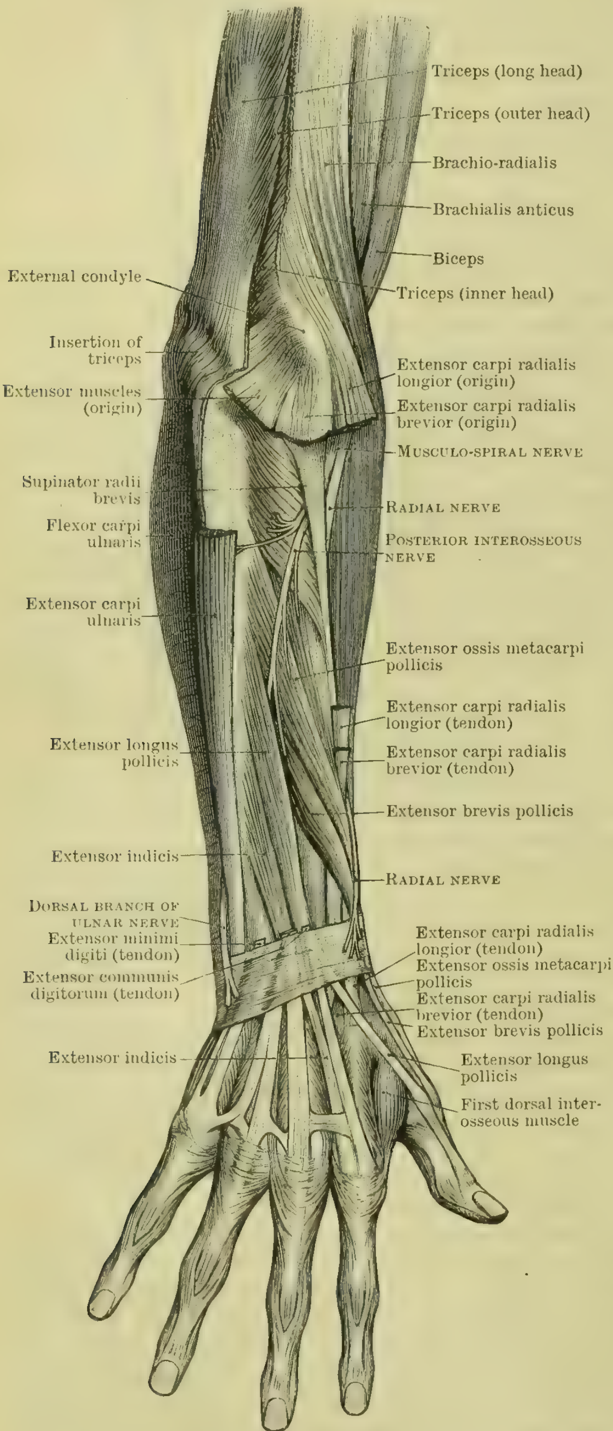


Fig. 436.—The Muscles of the Back of the Forearm (the superficial muscles have been reflected).

Subscapular Nerves.

There are three subscapular nerves (nn. subscapulares) (Figs. 429 and 431).

The **first or short subscapular nerve** is generally double, and there may be three trunks present. It arises from the posterior cord of the plexus behind the circumflex nerve, and from the fifth and sixth cervical nerves. It passes downwards behind the axillary artery and enters the subscapularis muscle.

The **second or lower subscapular nerve** also arises behind the circumflex from the posterior cord of the plexus, and from the fifth and sixth cervical nerves. Its origin is below and external to that of the first nerve. It courses outwards and downwards behind the axillary artery, and below the circumflex and musculo-spiral nerves to the teres major muscle. It supplies branches to the outer part of the subscapularis muscle and ends in the teres major.

The **third or long subscapular nerve** (n. thoraco-dorsalis) arises from the back of the posterior cord of the plexus, behind the musculo-spiral nerve, and from the sixth, seventh, and eighth cervical nerves, or from the seventh and eighth nerves only. It is directed downwards and outwards between the two previous nerves, behind the axillary artery and over the posterior wall of the axilla, in company with the subscapular artery, to the latissimus dorsi muscle, which it supplies on its anterior (inner) surface.

THORACIC NERVES.

The thoracic nerves are twelve in number, each nerve emerging below the corresponding vertebra and rib. Eleven of the series are intercostal, the twelfth lying below the last rib. The first, second, third, and twelfth nerves present peculiarities in their course and distribution. The other thoracic nerves, as already stated, are simple, and may be regarded as types both in course and distribution.

The **first thoracic nerve** is the largest of the series. It emerges from the spinal canal below the neck of the first rib, and divides in the first intercostal space into two very unequal, upper and lower, parts. The *upper* larger part ascends obliquely over the neck of the first rib, lying external to the superior intercostal artery, and enters the neck behind the subclavian artery and the pleura. It proceeds outwards upon the scalenus medius muscle and enters into the formation of the brachial plexus, as already described.

The *lower, intercostal part* of the nerve is much smaller in size. It courses forwards in the first intercostal space and supplies the intercostal muscles. It usually gives off no anterior branch to the skin of the chest and no lateral cutaneous branch.

In some cases a lateral cutaneous branch emerges from the side of the first intercostal space. This may be derived from the first nerve, or it may be the **intercosto-humeral nerve**, derived from the second thoracic nerve. In many cases an anterior cutaneous branch perforates the first intercostal space and supplies the skin on the front of the chest. This branch, similarly, is sometimes traceable to the second thoracic nerve.

Communications.—Besides its junction with the eighth cervical to form the brachial plexus, the first thoracic nerve effects the following communications:—(*a*) The last cervical or first thoracic ganglion of the sympathetic sends a gray ramus communicans to join the nerve on its appearance in the thorax. (*b*) The second thoracic nerve in a majority of cases communicates with the first. This communication varies considerably in size and distribution. It may reinforce the intercostal branch of the nerve, it may send one branch to the intercostal portion and another to the part of the nerve joining the brachial plexus, or it may consist of a nerve proceeding solely to join the brachial plexus by a junction in the first intercostal space with the part of the first thoracic nerve, which is engaged in forming the plexus.

The **second thoracic nerve** is of large size, though much smaller than the first. It passes forwards in the second intercostal space, lying at first in the subcostal groove between the external and internal intercostal muscles. At the level of the mid-axillary line it gives off a large lateral branch; continuing its course it pierces the internal intercostal muscle and lies upon the pleura; finally, at the

lateral border of the sternum, it passes forwards in front of the internal mammary artery and through the internal intercostal muscle, and the aponeurosis of the external intercostal muscle, and ends by supplying the skin of the front of the chest over the second intercostal space.

The nerve supplies the following branches:—

1. **Muscular branches** to the muscles of the second intercostal space.

2. **Cutaneous branches.** (*a*) **Anterior terminal branches** (rr. cutaneus anterior) to the skin over the second intercostal space (Fig. 438). (*b*) A large lateral cutaneous branch, the **intercosto-humeral nerve** (n. intercosto-brachialis) (Fig. 429, p. 581). This nerve pierces the intercostal muscles and the serratus magnus, and, crossing the axilla, extends to the arm. It pierces the deep fascia just beyond the posterior fold of the axilla, and can be traced down the arm as far as the interval between the internal condyle of the humerus and the olecranon process. It supplies an area of skin stretching across the armpit and along the posterior surface of the arm on the inner side as far as the elbow (Fig. 432, p. 586).

The intercosto-humeral nerve varies in size. It may pierce the first intercostal space, and it is often divisible into anterior and posterior branches, like the lateral branch of an ordinary intercostal nerve.

Communications.—(1) The intercosto-humeral nerve communicates with two adjacent nerves. Either before or after piercing the fascia of the axilla it is joined by the lesser internal cutaneous nerve of the brachial plexus. It also communicates with the posterior part of the lateral branch of the third intercostal nerve by means of the branches distributed to the floor and boundaries of the axilla. It may supply the axillary arches, when present. (2) Besides the branches referred to, the second thoracic nerve in many cases transmits a nerve to the brachial plexus, which becomes incorporated with the first thoracic nerve after passing over the neck of the second rib. This branch is inconstant. As already mentioned, it may join only the intercostal part of the first thoracic nerve, it may join the brachial plexus only, or it may send branches to both parts of the first thoracic nerve. (3) Besides the communications effected by branches of the second thoracic nerve in its course, it also receives a gray *ramus communicans* from the second thoracic ganglion of the sympathetic cord in the thorax. It probably also sends to the sympathetic the first white *ramus communicans*, though this is not known with certainty.

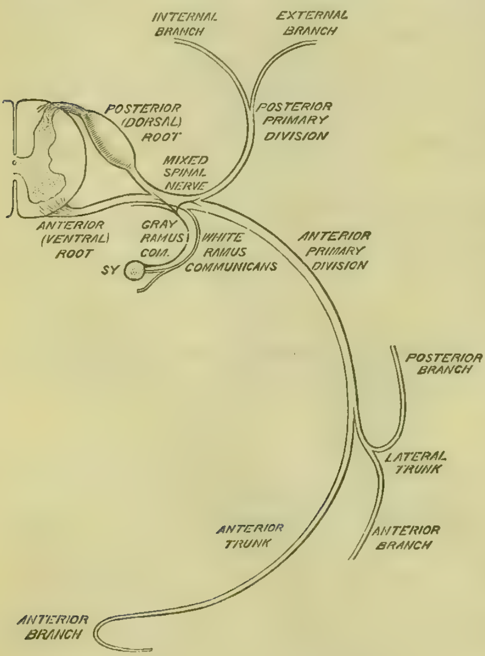


Fig. 437.—Scheme of the Distribution of a Typical Spinal Nerve.

The **third thoracic nerve** only differs from a typical thoracic nerve in one respect. Its **lateral branch** divides in the usual way into anterior and posterior parts, of which the latter is carried to the arm and supplies an area of skin on the posterior half of the inner side near the root of the limb. It effects a junction with the intercosto-humeral (Fig. 429, p. 581).

The **fourth, fifth, and sixth thoracic nerves** have a course and distribution which is simple and typical. Except for the peculiarities above mentioned, the second and third thoracic nerves have a similar distribution.

The nerves appear on the posterior wall of the thorax, in the subcostal groove of the corresponding rib. They extend forwards between the intercostal muscles as far as the middle of the chest wall, lying at a lower level than the intercostal vessels. At the side of the chest each nerve passes obliquely through the internal intercostal muscle, and comes to lie upon the pleura, triangularis sterni muscle, and internal mammary artery. Thereafter, piercing the fibres of the internal intercostal muscle and the aponeurosis of the external intercostal muscle, each nerve ends by supplying the

skin of the front of the chest, over an area corresponding to the inner or anterior part of the intercostal space to which it belongs.

Branches. — Each intercostal nerve supplies, in addition to the anterior terminal cutaneous branches, *muscular branches* to the intercostal muscles and a **lateral trunk** (r. cutaneus lateralis), which, piercing the intercostal muscles and the serratus magnus, divides into anterior and posterior branches for the innervation of the skin over the side of the chest. Each area of skin thus innervated is continuous anteriorly with the area innervated by the anterior terminal branches of the same nerves, and posteriorly with the areas supplied by their posterior primary divisions.

The upper six intercostal nerves supply the muscles of the first six intercostal spaces and the triangularis sterni (3, 4, 5, 6). The second, third, fourth, fifth, and sixth nerves supply the skin of the front of the chest: the second, opposite the manubrio-sternal joint; the sixth, opposite the base of the xiphoid cartilage. Their lateral branches supply the skin of the side of the chest, the second (intercosto-humeral) and the third in part being drawn out on to the arm. The fourth supplies the nipple (Fig. 438).

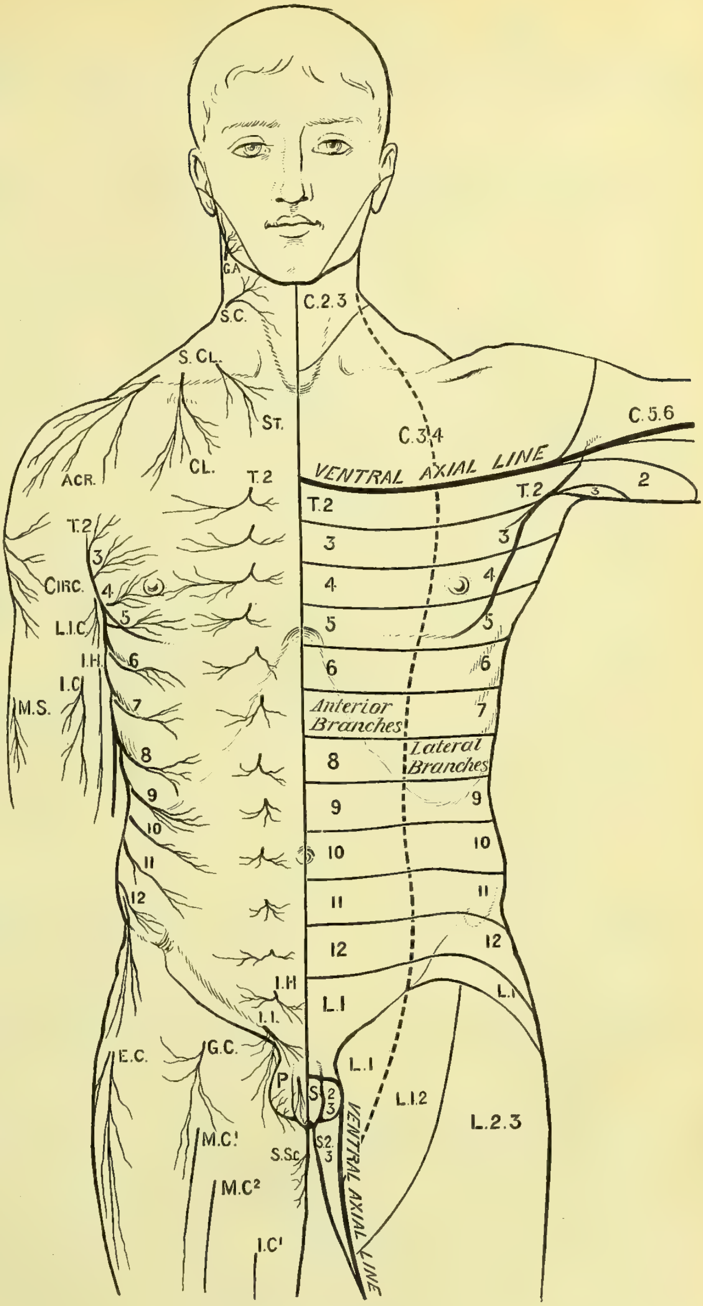


Fig. 438.—The Distribution of Cutaneous Nerves on the Front of the Trunk.

On one side the distribution of the several nerves is represented, the letters indicating their nomenclature.

G.A, Great auricular nerve; S.C, Superficial cervical nerve; S.Cl, Supraclavicular nerves; Acr, Acromial; Cl, Clavicular; St, Sternal; T.2-12, Lateral and anterior branches of thoracic nerves; I.H, Ilio-hypogastric nerve; I.I, Ilio-inguinal nerve; Circ, Cutaneous branch of circumflex nerve; L.I.C, Lesser internal cutaneous nerve; I.H, Intercosto-humeral; I.C, Internal cutaneous; M.S, Cutaneous branch of musculo-spiral nerve; E.C, External cutaneous nerves; G.C, Genito-crural nerve; M.C$^{1\ 2}$, Middle cutaneous nerves; I.C^1, Branch of internal cutaneous nerve; P, Branches of pudic nerve; S.Sc, Branches of small sciatic nerve.

On the other side a schematic representation is given of the areas supplied by the above nerves, the numerals indicating the spinal origin of the branches of distribution to each area.

Communications.—Each of these intercostal nerves communicates with the sympathetic cord and ganglia by two branches—a *white ramus communicans* to the corresponding sympathetic ganglion or the adjacent part of the sympathetic cord; and a *gray ramus communicans*, which passes to each nerve from the corresponding ganglion.

The **seventh, eighth, ninth, tenth, and eleventh thoracic nerves** only differ from the preceding nerves in regard to a part of their course and distribution. Each has the same course and communications as the preceding nerves in the thoracic wall. In addition, these nerves have a further course and distribution in the abdominal wall. Each nerve traverses its intercostal space in the way described. At the anterior end of the space, the nerve pierces the attachment of the diaphragm and the transversalis abdominis muscles to the costal cartilages, and courses forwards in the abdominal wall between the transversalis and obliquus internus muscles. The nerve then passes between the rectus muscle and the posterior layer of its sheath, and eventually reaches the anterior abdominal wall and becomes cutaneous by piercing the rectus itself and the anterior layer of its sheath.

Muscular Branches.—The lower intercostal nerves supply the intercostal muscles of the spaces in which they lie; and in the abdominal wall they innervate the transversalis, obliqui, and rectus abdominis. The branches arise from the main trunk as well as from its lateral and anterior branches. (The ninth, tenth, and eleventh nerves are described as assisting in the innervation of the diaphragm by communications with the phrenic nerve.)

Cutaneous Branches.—These are lateral and anterior. The **lateral branches** divide into anterior and posterior parts, and, becoming superficial along the line of inter-digitation of the obliquus externus muscle with the serratus magnus and latissimus dorsi, they are directed more obliquely downwards than the lateral branches of the higher intercostal nerves, and are distributed to the skin of the loin as low down as the buttock. The lateral branch of the eleventh nerve can be traced over the iliac crest (Fig. 438).

The **anterior branches** are small. That of the seventh nerve innervates the skin at the level of the ensiform cartilage. The eighth and ninth appear between the ensiform cartilage and the umbilicus; the tenth nerve supplies the region of the umbilicus; and the eleventh, the area immediately below the umbilicus.

The cutaneous branches of these nerves, including the posterior primary divisions, thus supply continuous belts of skin, which can be mapped out on the body from the vertebral column behind to the middle line in front. These areas are not placed horizontally, but tend to be drawn downwards as the series is followed from the upper to the lower nerves.

The **twelfth thoracic nerve** is peculiar in its course and distribution. It emerges below the last rib (Fig. 439), and passes outwards and downwards in the posterior abdominal wall under cover of the psoas muscle, and between the external arcuate ligament and the quadratus lumborum muscle; it pierces the transversalis muscle, and courses forwards in the interval between it and the obliquus internus to the sheath of the rectus muscle. After piercing the posterior layer of the sheath, the rectus muscle, and the anterior layer of the sheath, it terminates by supplying the skin of the anterior abdominal wall midway between the umbilicus and the pubis. The branches of the nerve are **muscular**, to the transversalis, obliqui, rectus, and pyramidalis muscles of the abdominal wall, and **cutaneous branches**, two in number—an *anterior terminal branch*, which supplies the skin of the anterior abdominal wall midway between the umbilicus and the pubis, and a large *lateral cutaneous* (iliac) *branch*, which, passing obliquely downwards through the lateral muscles of the abdominal wall, becomes superficial above the iliac crest, a couple of inches behind the anterior superior spine. It supplies the skin of the buttock as far down as a point below and in front of the great trochanter of the femur (Fig. 442, p. 603).

The twelfth thoracic nerve, in many cases, receives a **communicating branch** from the eleventh, near its origin, and still more frequently sends a fine branch to join the origin of the first lumbar nerve in the psoas muscle. It may communicate also with the ilio-hypogastric nerve, as they lie together in the abdominal wall.

THE LUMBO-SACRAL PLEXUS.

The lumbo-sacral plexus is formed by the union of the anterior primary divisions of the remaining spinal nerves—five lumbar, five sacral, and one coccygeal. Frequently,

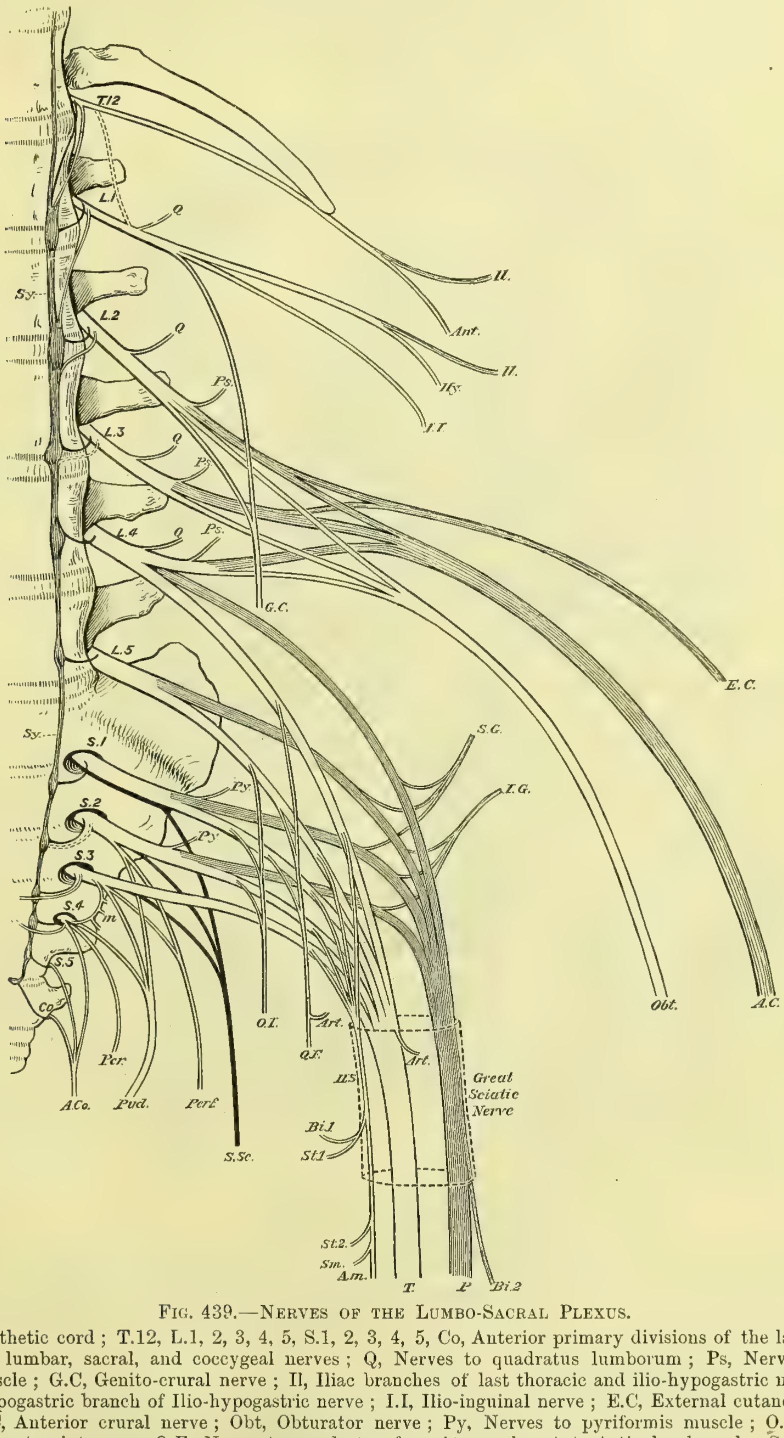


Fig. 439.—Nerves of the Lumbo-Sacral Plexus.

Sy, Sympathetic cord ; T.12, L.1, 2, 3, 4, 5, S.1, 2, 3, 4, 5, Co, Anterior primary divisions of the last thoracic, the lumbar, sacral, and coccygeal nerves ; Q, Nerves to quadratus lumborum ; Ps, Nerves to psoas muscle ; G.C, Genito-crural nerve ; Il, Iliac branches of last thoracic and ilio-hypogastric nerves ; Hy, Hypogastric branch of Ilio-hypogastric nerve ; I.I, Ilio-inguinal nerve ; E.C, External cutaneous nerve ; A.C, Anterior crural nerve ; Obt, Obturator nerve ; Py, Nerves to pyriformis muscle ; O.I, Nerve to obturator internus ; Q.F, Nerve to quadratus femoris muscle ; Art, Articular branch ; S.G, Superior gluteal nerve ; I.G, Inferior gluteal nerve ; P, Peroneal nerve ; Bi.2, Nerve to short head of biceps muscle ; T, Tibial nerve ; Art, Articular branch ; H.S, Nerve to the hamstring muscles ; Bi.1, Nerves to biceps (long head), and St.1, to semitendinosus ; St.2, Semitendinosus ; Sm, Semimembranosus ; A.m, Adductor magnus ; S.Sc, Small sciatic nerve ; Perf, Perforating cutaneous nerve ; Pud, Pudic nerve ; M, Muscular branches ; Per, Perineal branch of fourth sacral ; A.Co, Anterior sacro-coccygeal nerve.

a fine communicating branch of the twelfth thoracic nerve joins the first lumbar nerve near its origin.

Of the nerves in question the first sacral is generally the largest in size, the nerves diminishing gradually above and rapidly below the first sacral. The plexus, for the most part, forms the nerves destined for the supply of the lower limb. In addition, however, nerves arise at its upper limit which are distributed to the trunk above the level of the limb, and at the lower end of the plexus nerves arise for the supply of the perineum.

Partly for convenience of description, and partly on account of the differences in position and course of some of the nerves emanating from it, the plexus is subdivided into three subordinate parts—lumbar, sacral or sciatic, and pudendal plexuses. There is, however, no strict line of demarcation between these parts.

The **lumbar plexus** is formed by the first four lumbar nerves, and is often joined by a branch from the twelfth thoracic nerve as well. It is limited below by the fourth lumbar nerve (n. furcalis), which also enters into the composition of the sciatic or sacral plexus. The nerves of the lumbar plexus are formed in the loin, and supply that region as well as part of the lower limb. They are separated from the nerves of the sacral portion of the plexus by the articulation of the innominate bone with the sacrum.

The **sacral** or **sciatic plexus** is formed by the fourth and fifth lumbar, and first two or three sacral nerves. It is generally limited below by the third sacral nerve (n. bigeminus), which also assists in forming the pudendal plexus. The nerves of the sacral plexus are placed on the posterior wall of the pelvis, and are destined almost entirely for the lower limb.

The **pudendal plexus** is formed by the second, third, fourth, and fifth sacral nerves, and the minute coccygeal nerve. It is placed on the back wall of the pelvis and supplies branches mainly to the perineum.

Communications with the Sympathetic.—Each of these nerves has communications with the gangliated cord of the sympathetic in the abdomen and pelvis.

Gray Rami Communicantes.—From the lumbar and sacral ganglia long slender *gray rami communicantes* are directed backwards and outwards over the bodies of the vertebræ, and (in the lumbar region) beneath the origins of the psoas muscle, to reach the anterior primary divisions of the nerves. These branches are irregular in their arrangement. A given nerve may receive branches from two ganglia, or one ganglion may send branches to two nerves. The rami are longer in the loin than in the pelvis, owing to the projection of the lumbar portion of the vertebral column.

White Rami Communicantes.—Certain lumbar and sacral nerves are also connected with the abdominal and pelvic sympathetic by means of *white rami communicantes.* From the first two, and possibly also the third and fourth lumbar nerves, white rami communicantes are directed forwards, either independently or incorporated with the corresponding gray rami, to join the upper part of the lumbar gangliated cord. The fifth lumbar nerve and the first sacral nerves are unprovided with white rami communicantes. From the third, and sometimes also the second and fourth sacral nerves, white rami (visceral branches) pass inwards, and, crossing over (without joining) the gangliated cord, join the pelvic plexus of the sympathetic. The fifth sacral and coccygeal nerves possess no white rami communicantes.

THE LUMBAR PLEXUS.

The lumbar plexus is formed by the anterior primary divisions of the first three and a part of the fourth lumbar nerves, with the addition, in some cases, of a small branch from the twelfth thoracic nerve. The nerves increase in size from above downwards (Fig. 440).

Position and Constitution.—The plexus is placed deeply in the substance of the psoas muscle, in front of the transverse processes of the lumbar vertebræ. The nerves, on emerging from the intervertebral foramina, are connected as above described with the sympathetic system, and then divide in the following manner in the substance of the psoas muscle:—The first and second nerves divide into upper and lower branches. The upper branch of the first nerve (which may be joined by the branch from the twelfth thoracic nerve) forms two nerves, **ilio-hypogastric** and

ilio-inguinal. The lower branch of the first joins the upper branch of the second nerve, to produce the **genito-crural nerve**. The lower branch of the second nerve, the whole of the third, and that part of the fourth nerve engaged in the constitution of the plexus divide each into two unequal parts—smaller *anterior* and larger *posterior parts*. The smaller anterior portions combine together to form the **obturator nerve**, which is thus formed by the second, third, and fourth lumbar

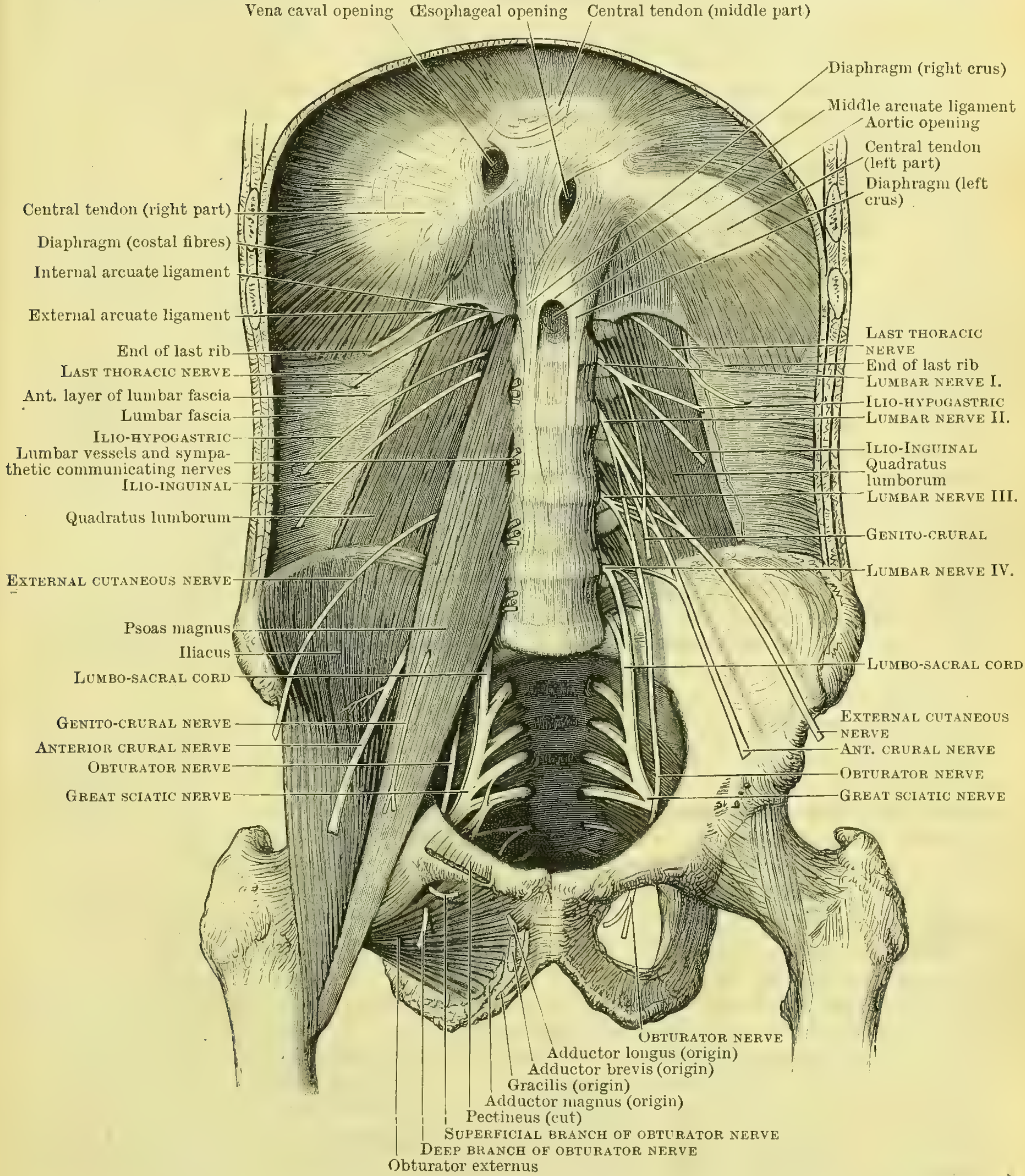


FIG. 440.—VIEW OF THE POSTERIOR ABDOMINAL WALL, TO SHOW THE MUSCLES AND THE NERVES OF THE LUMBO-SACRAL PLEXUS.

nerves. The root from the second nerve is not always present. The larger posterior portions of the same nerves combine together to form the **anterior crural nerve.** From the back of the posterior parts of the second and third nerves, the **external cutaneous nerve** arises. The nerves also provide, near their origins, irregular **muscular branches**, for the psoas and quadratus lumborum muscles. The following is a list of the nerves which spring from the lumbar plexus (Figs. 439 and 440):—

(1) Muscular branches to the quadratus lumborum and psoas.
(2) Ilio-hypogastric.
(3) Ilio-inguinal.
(4) Genito-crural.
(5) External cutaneous.
(6) Obturator.
(7) Anterior crural.

The nerves to the **quadratus lumborum muscle** arise independently from the first three or four lumbar nerves (and sometimes also from the twelfth thoracic nerve). The nerves to the **psoas muscles** arise from the second and third lumbar nerves, with additions, in some cases, from the first or fourth. They are often associated in their origin with the nerve to the iliacus from the anterior crural. The **psoas minor**, when present, is innervated by the highest of the nerves in question.

The ilio-hypogastric and ilio-inguinal nerves closely resemble in their course and distribution the lower thoracic nerves, with which they are in series.

The **ilio-hypogastric nerve** (n. ilio-hypogastricus) is the highest branch of the first lumbar nerve. It receives fibres also from the twelfth thoracic, when that nerve communicates with the first lumbar nerve. After traversing the psoas muscle obliquely, it appears at its outer border on the surface of the quadratus lumborum and behind the kidney. It courses through the loin, lying between the transversalis and obliquus internus muscles, above the crest of the ilium. About an inch in front of the anterior superior spine it pierces the obliquus internus, and continues its course in the groin beneath the aponeurosis of the obliquus externus. It finally becomes cutaneous in the anterior abdominal wall, by piercing the aponeurosis of the obliquus externus about an inch and a half above the external abdominal ring (Fig. 442, p. 603).

Its **branches** are—(1) *muscular* to the muscles of the abdominal wall; and (2) *cutaneous branches*, two in number. The **iliac branch** corresponds with the lateral branch of an intercostal nerve, and, after piercing the obliquus internus and obliquus externus, becomes cutaneous just above the iliac crest, below and behind the iliac branch of the last thoracic nerve. It is small, and may be absent. It is distributed to the skin over the upper part of the outer side of the buttock, in continuity with the cutaneous branch of the posterior primary division of the first lumbar nerve. The **hypogastric branch** is the anterior terminal branch of the nerve. It supplies the skin of the anterior abdominal wall below the level of the last thoracic nerve and above the pubis.

The **ilio-inguinal nerve** (n. ilio-inguinalis) is the second branch given off from the first lumbar nerve. It also may receive fibres from the last thoracic nerve. Not unfrequently the ilio-hypogastric and ilio-inguinal nerves are represented for a longer or shorter part of their course by a single trunk. When separate the nerve takes a course similar to that of the ilio-hypogastric nerve, but at a lower level, as far as the anterior abdominal wall. It then pierces the obliquus internus further forward and lower down than the ilio-hypogastric; and coursing forwards beneath the aponeurosis of the obliquus externus, just above Poupart's ligament, it becomes superficial after passing through the external abdominal ring and external spermatic fascia (Fig. 442, p. 603).

Its branches are *muscular* to the muscles of the abdominal wall, among which it passes, and *cutaneous branches*, which innervate the skin (1) of the anterior abdominal wall over the symphysis pubis, (2) of the thigh over the upper and inner part of Scarpa's triangle, and (3) of the upper part of the scrotum, and root and dorsum of the penis (of the mons Veneris and labium majus in the female). These last-named branches are contiguous to branches of the pudendal and pudic nerves. No lateral cutaneous branch arises from the ilio-inguinal nerve. It thus corresponds, like the hypogastric part of the ilio-hypogastric nerve, to the anterior trunk of a typical thoracic nerve.

The **genito-crural nerve** (n. genito-femoralis) usually arises by two independent roots from the front of the first and second lumbar nerves, which unite in the substance of the psoas to form a slender trunk. It appears on the posterior abdominal wall, lying on the psoas magnus, internal to the psoas parvus, and, piercing the psoas fascia, it extends downwards on the outer side of the common and external iliac vessels and behind the ureter to Poupart's ligament (Fig. 440, p. 599). At a variable point above that ligament it divides into genital and crural branches. The **genital branch** is a minute nerve. It crosses the terminations of the external iliac vessels, and,

along with the vas deferens and spermatic vessels, enters the inguinal canal at the internal abdominal ring. It terminates by supplying small branches to the skin of the scrotum and adjacent part of the thigh. In the female it accompanies the round ligament to the labium majus. This nerve gives off in its course the following small branches: (1) to the external iliac artery; (2) to the cremaster muscle; (3) to communicate with the spermatic plexus of the sympathetic. The **crural branch** continues the course of the parent nerve into the thigh, lying on the outer side of the femoral artery. It becomes cutaneous by passing through the saphenous opening or the iliac portion of the fascia lata, and supplies an area of skin over Scarpa's triangle, external to that supplied by the ilio-inguinal (Fig. 442, p. 603). It communicates in the thigh with the middle cutaneous branch of the anterior

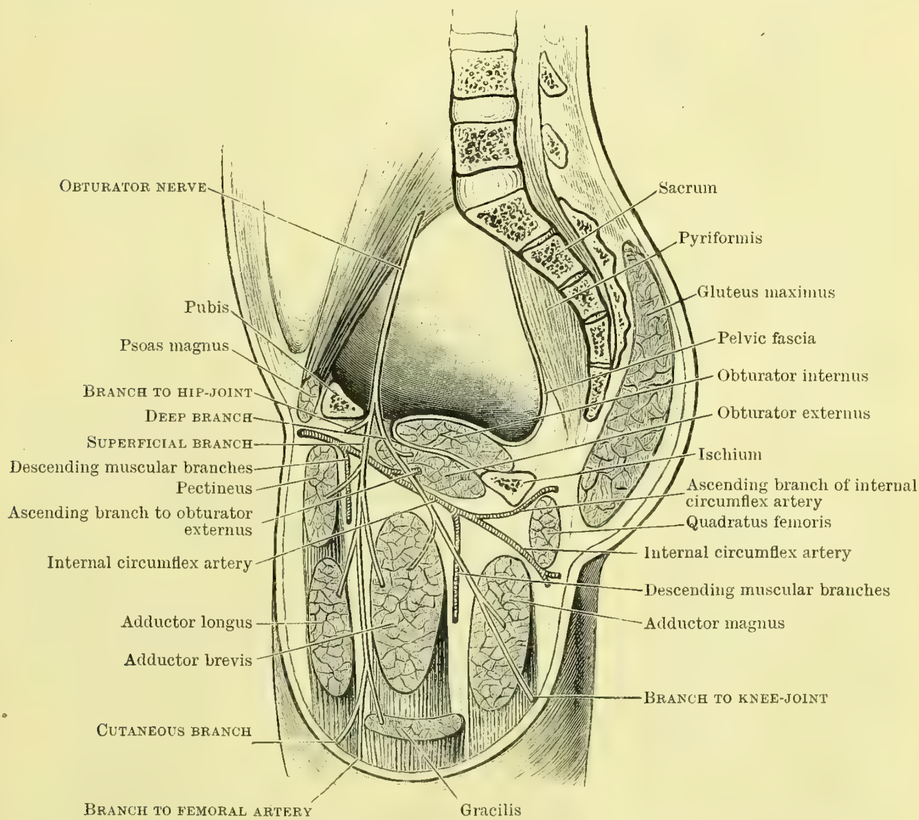


FIG. 441.—SCHEME OF THE COURSE AND DISTRIBUTION OF THE OBTURATOR NERVE.

crural nerve. Before piercing the deep fascia it gives a minute branch to the femoral artery.

The **external cutaneous nerve** (n. cutaneus femoris lateralis) is only distributed to skin (Fig. 440). It arises from the back of the lumbar plexus, and usually from the second and third lumbar nerves. Emerging from the psoas muscle at its outer border, the nerve crosses the iliacus muscle, beneath the fascia iliaca, to reach the anterior superior iliac spine. It enters the thigh beneath the outer extremity of Poupart's ligament, and either over, under, or through the origin of the sartorius muscle. It extends down the outer side of the front of the thigh for a few inches, lying at first beneath the fascia lata, and afterwards in a tubular investment of the fascia. It gives off small branches in this part of its course, and finally, piercing the fascia about four inches below the anterior superior iliac spine, it separates into anterior and posterior terminal branches. The **anterior branch** is the larger, and is distributed on the outer side of the front of the thigh almost to the knee. The smaller **posterior branch** supplies the skin of the outer side of the buttock below the great trochanter and of the upper two-thirds of the outer side of the thigh (Fig. 442, p. 603).

Obturator Nerve.

The **obturator nerve** (n. obturatorius) supplies the muscles and skin on the inner side of the thigh. It arises in the substance of the psoas muscle by three roots placed in front of those of the anterior crural nerve, and derived from the second, third, and fourth lumbar nerves (Fig. 440, p. 599). Sometimes the root from the second nerve is absent. Passing vertically downwards, the nerve emerges from the psoas at its inner border, behind the common iliac, and on the outer side of the internal iliac vessels. It passes forwards below the pelvic brim in company with the obturator artery to the obturator groove of the thyroid foramen, through which it reaches the thigh. While in the obturator groove it separates into its two main branches, named superficial and deep (Fig. 441, p. 601).

The **superficial branch** enters the thigh in front of the obturator externus and adductor brevis muscles, and beneath the pectineus and adductor longus. In the middle third of the thigh it is found coursing along the inner border of the adductor longus, anterior to the gracilis; and it finally divides into two slender terminal filaments, of which one enters Hunter's canal and ends on the femoral artery, the other supplies the skin for a variable distance on the inner side of the thigh and joins in the obturator (subsartorial) plexus.

The branches of the superficial part of the nerve are:—

1. An **articular branch** to the hip joint which arises from the nerve as soon as it enters the thigh, and supplies the joint through the acetabular notch.

2. **Muscular branches** to the adductor longus, gracilis, adductor brevis (usually), pectineus (occasionally). The last-named muscle is not usually supplied from the obturator nerve.

3. A **cutaneous branch** of very variable size forms one of the terminal branches (Fig. 442). It becomes superficial between the gracilis and adductor longus, in the middle third of the thigh, and may supply the skin of the lower two-thirds of the thigh in its inner side. It is generally of small size, and is connected with branches of the internal cutaneous and internal saphenous nerves behind the sartorius muscle to form the **obturator (subsartorial) plexus**. The branch from the internal saphenous nerve to the plexus passes inwards behind the sartorius after piercing the aponeurotic covering of Hunter's canal. The branch from the internal cutaneous nerve is generally superficial at the point of formation of the plexus.

4. The **branch to the femoral artery** is the other terminal branch of the nerve. It enters Hunter's canal along the inner edge of the adductor longus, and ramifies over the lower part of the artery.

5. A fine **communicating branch** in front of the hip joint sometimes joins the anterior crural nerve.

The **deep part of the obturator nerve** reaches the thigh by piercing the obturator externus muscle. It passes downwards between the adductor brevis and adductor magnus muscles. After passing obliquely through the adductor magnus, it appears in the popliteal space on the popliteal vessels, and terminates by piercing the posterior ligament and supplying the knee joint.

Its branches are:—(1) **muscular branches** to the obturator externus, adductor magnus, and (when the muscle is not supplied by the superficial part of the nerve) the adductor brevis. The branch to the obturator externus arises before the nerve enters the muscle, in the obturator groove. The nerve to the adductor magnus is given off as the obturator nerve passes through the substance of the muscle. (2) An **articular terminal branch** is supplied to the back of the knee joint.

Anterior Crural Nerve.

The **anterior crural nerve** (n. femoralis) is the great nerve for the muscles and skin of the thigh. It arises in the substance of the psoas muscle, from the back of the second, third, and fourth lumbar nerves, behind the obturator nerve. Passing obliquely through the psoas muscle, it emerges from its outer border in the false pelvis (Fig. 440, p. 599). Passing downwards in the groove between the psoas and iliacus, it enters the thigh beneath Poupart's ligament, external to the femoral

sheath and femoral vessels. In Scarpa's triangle it breaks up into a large number of branches, among which the external circumflex artery passes.

The **branches** of the anterior crural nerve, which are (1) muscular, (2) articular, and (3) cutaneous, arise in the following way:—

In the abdomen a muscular branch arises from the outer side of the nerve and enters the iliacus muscle.

In Scarpa's triangle the terminal muscular, articular, and cutaneous branches of the nerve arise in the form of a large bundle of nerves.

1. The **muscular branches** supply the pectineus, sartorius, and quadriceps extensor. The nerve to the pectineus arises close to Poupart's ligament, and coursing obliquely downwards and inwards behind the femoral vessels enters the muscle at its outer border. It is not unfrequently double. It sometimes gives off a fine communicating branch to the superficial part of the obturator nerve. The nerves to the sartorius are in two sets: an outer short set of nerves associated with the outer part of the middle cutaneous nerve, which enter the upper part of the muscle; and an inner longer set which are associated with the inner part of the middle cutaneous nerve, and supply the middle of the muscle. The parts of the quadriceps extensor are supplied by several branches. The vastus externus and rectus femoris are supplied on their deep surface by separate nerves which are accompanied by branches of the external circumflex artery. The crureus muscle is supplied superficially by a nerve which passes through the muscle, and innervates also the subcrureus. It also receives fibres from one of the nerves to the vastus internus. The vastus internus muscle is supplied by two nerves: an upper trunk, which supplies the higher part of the muscle, and sends fibres to the crureus as well; and a lower trunk, which descends on the outer side of the femoral artery along with the internal saphenous nerve, and passing beneath the sartorius, over or under the aponeurotic covering of Hunter's canal, enters the inner side of the vastus internus muscle. This nerve gives off a small branch which enters the medullary canal of the femur.

2. The **articular branches** supply the hip and knee joints. The articular branch to the hip joint arises from the nerve to the rectus femoris, and is accompanied by branches from the external circumflex artery. The articular branches to the knee joint are four in number. Three of them arise from the nerves to the vastus externus, crureus, and vastus internus, which, after the muscular nerves are given off, are continued downwards to the knee joint along the front of the femur. A fourth articular branch arises (sometimes) from the internal saphenous nerve.

3. The **cutaneous branches** are the middle and internal cutaneous, and the internal saphenous nerves (Fig. 442).

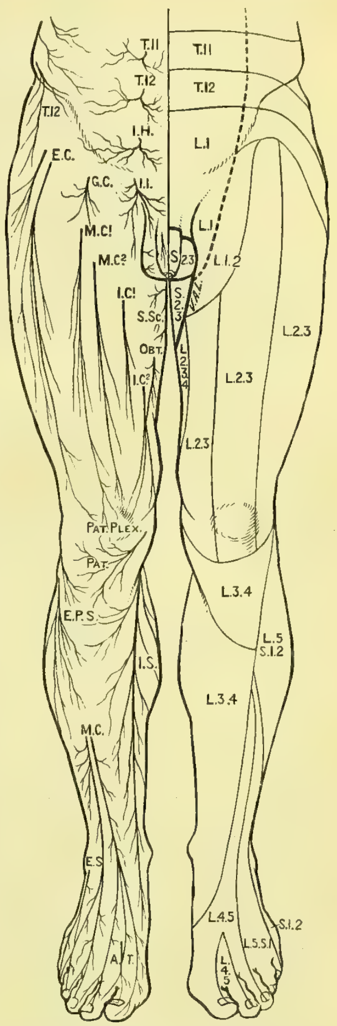


Fig. 442.—Distribution of Cutaneous Nerves on the Front of the Lower Limb.

On the one side the distribution of the several nerves is represented, the letters indicating their nomenclature.

T.11, Branches of eleventh thoracic nerve; T.12, Branches of twelfth thoracic nerve; I.H, Ilio-hypogastric; I.I, Ilio-inguinal; E.C, External cutaneous; G.C, Genito-crural; M.C^{1},^{2}, Middle cutaneous; I.C^{1},^{2}, Internal cutaneous; Obt, Obturator; S.Sc, Small sciatic; Pat. Plex, Patellar plexus; Pat, Patellar branch of internal saphenous; E.P.S, Sural branches of peroneal nerve; I.S, Internal saphenous; M.C, Musculo-cutaneous; E.S, External saphenous; A.T, Anterior tibial.

On the other side a schematic representation is given of the areas supplied by the above nerves, the letters indicating the spinal origin of the branches of distribution to each area.

The **middle cutaneous nerve** arises in two parts, an *external* and an *internal*

branch, in the upper part of Scarpa's triangle. The two branches descend vertically and become cutaneous by piercing the fascia lata over the upper third of the sartorius muscle. They carry muscular branches to the sartorius, and the external branch in many cases pierces the muscle. These two nerves supply the skin of the lower three-fourths of the front of the thigh, between the external cutaneous nerve on the outer side and the internal cutaneous on the inner side. They reach down to the front of the patella, and there assist in the formation of the patellar plexus. The external branch communicates in the upper third of the thigh with twigs from the crural branch of the genito-crural nerve.

The **internal cutaneous nerve** lies at first in Scarpa's triangle on the outer side of the femoral vessels. At the apex of the triangle it crosses over the femoral vessels, and is directed downwards over or through the sartorius muscle, and beneath the fascia lata to the lower third of the thigh. It is distributed to the skin of the lower two-thirds of the thigh on the inner side by means of three branches—upper, middle, and lower.

The *upper branch* may be represented by two or more twigs. It arises from the main nerve near its origin, and pierces the fascia lata near the apex of Scarpa's triangle. It is distributed to the skin of the upper part of the thigh, along the line of the saphenous vein. The *middle* or *anterior branch* is a larger nerve. It separates from the lower branch at the apex of Scarpa's triangle, and passing over the sartorius muscle becomes cutaneous in the middle third of the thigh on the inner side. It supplies the skin of the lower half of the thigh on the inner side, extending as low as the knee, where it joins in the formation of the patellar plexus.

The *lower* or *internal branch* represents the termination of the nerve. It passes down the inner side of the thigh over the sartorius muscle, and communicates in the middle third of the thigh with the internal saphenous and obturator nerves to form the obturator plexus. Piercing the fascia lata on the inner side of the thigh in the lower third, it ramifies over the inner side of the knee, and assists in the formation of the patellar plexus.

The size of the internal cutaneous nerve varies with the size of the cutaneous part of the obturator, and of the internal saphenous nerve.

The **long** or **internal saphenous nerve** (n. saphenus) may be regarded as the terminal branch of the anterior crural nerve. It is destined for the skin of the leg and foot. From its origin in Scarpa's triangle it descends alongside the femoral vessels to Hunter's canal. In the canal it crosses over the femoral sheath from without inwards. At the lower end of the canal, accompanied by the superficial branch of the anastomotic artery, it passes over the tendon of the adductor magnus, and opposite the inner side of the knee joint becomes cutaneous by passing between the sartorius and gracilis muscles. The nerve then extends down the leg along with the internal saphenous vein, and coursing over the front of the inner ankle it terminates at the middle of the inner border of the foot.

Branches.—1. A **communicating branch** arises in Hunter's canal, and passing inwards beneath the sartorius joins with branches of the obturator nerve in forming the obturator plexus.

2. The **patellar branch** arises at the lower end of Hunter's canal, and piercing the sartorius muscle is directed downwards and forwards below the patella, and over the inner tuberosity of the tibia to the front of the knee and upper part of the leg. It enters into the formation of the patellar plexus.

3. An **articular branch** sometimes arises from the nerve at the inner side of the knee.

4. The **terminal branches** of the internal saphenous nerve are distributed to the skin of the front and inner side of the leg, and the posterior half of the dorsum and inner side of the foot.

Patellar plexus.—This plexus consists of fine communications beneath the skin in front of the knee, between the branches of the cutaneous nerves supplying that region. The nerves which enter into its formation are the patellar branch of the internal saphenous, internal and middle cutaneous nerves, and sometimes the external cutaneous nerve.

The **accessory obturator nerve** (n. obturatorius accessorius, n. accessorius anterioris cruralis, Winslow) is only occasionally present (29 per cent, Eisler). It arises from the third, or third and fourth lumbar nerves, between the roots of the obturator and anterior crural nerves. Associating itself with the obturator, from which, however, it is quite separable, it appears in the abdomen at the inner side of the psoas muscle, and coursing over the pelvic brim behind the external iliac vessels, it leaves the obturator nerve, and enters the thigh in front of the pubis.

In the thigh, behind the femoral vessels, it ends usually in three branches: a nerve which replaces the branch from the anterior crural to the pectineus, a nerve to the hip joint, and a nerve which communicates with the superficial part of the obturator nerve. In some cases it only supplies the nerve to the pectineus; more rarely it is of considerable size, and reinforces the obturator nerve in the innervation of the adductor muscles.

The accessory obturator nerve was first described by Winslow as the *n. accessorius anterioris cruralis.* Schmidt later described it in great detail, and gave it the name it now bears. It is more closely associated with the anterior crural than with the obturator. Its origin is behind the roots of the obturator: it is separated, like the anterior crural, from the obturator by the pubic bone, and its chief branch to the pectineus muscle replaces the normal branch from the anterior crural nerve. On the other hand, for a part of its course it accompanies the obturator, and in rare cases it may replace branches of that nerve.

THE SACRAL OR SCIATIC PLEXUS.

The sacral or sciatic portion of the lumbo-sacral plexus is destined almost entirely for the lower limb. It is usually formed by the anterior primary divisions of a part of the fourth lumbar nerve (n. furcalis), the fifth lumbar, the first, second, and third sacral nerves (n. bigeminus).

Communications with the Sympathetic.—Each of the nerves named is connected to the lumbar or pelvic sympathetic by *gray rami communicantes*, as already described; and *white rami communicantes* pass usually from the third and sometimes also from the second and fourth sacral nerves to join the pelvic plexus of the sympathetic.

Position and Constitution.—The plexus is placed on the back wall of the pelvis between the parietal pelvic fascia and the pyriformis muscle. In front of it are the pelvic colon, the internal iliac vessels, and the ureter.

The formation of the plexus occurs by the convergence of the nerves concerned towards the lower part of the great sacro-sciatic foramen, and their union to form a broad triangular band, the apex of which is continued through the great sacro-sciatic foramen below the pyriformis muscle into the buttock as the **great sciatic nerve.** From the anterior and posterior surfaces of this triangular band numerous small branches arise, which are distributed to the parts in the neighbourhood of the origin of the nerve.

The great sciatic nerve ends in the thigh by dividing into two large nerves, the **tibial** (internal popliteal), and **peroneal** (external popliteal). In many cases these two nerves are distinct from their origin, and are separated sometimes by fibres of the pyriformis muscle. In all cases on removal of the sheath investing the great sciatic nerve the tibial and peroneal nerves can be traced up to the plexus, from which they invariably take origin by distinct and separate roots.

The descending branch of the fourth lumbar nerve (n. furcalis) after emerging from the inner border of the psoas muscle internal to the obturator nerve, divides behind the iliac vessels into anterior and posterior (ventral and dorsal) parts, each of which joins a corresponding part of the fifth lumbar nerve. The anterior primary division of the fifth lumbar nerve descends over the ala of the sacrum, and divides into anterior and posterior parts, which are joined by the corresponding parts of the fourth lumbar nerve. The two resulting trunks are sometimes called the **lumbo-sacral cord.** The first and second sacral nerves pass almost horizontally outwards from the anterior sacral foramina, and divide in front of the pyriformis into similar anterior and posterior parts. The third sacral nerve (n. bigeminus) divides into upper and lower parts. The lower part is concerned in forming the pudendal plexus. The upper part is directed outwards, and slightly upwards, towards the preceding nerve, and does not separate into two parts, but remains undivided.

These trunks combine to form the sciatic or sacral plexus, and its main subdivisions, in the following way. Lying in apposition, and converging to the lower part of the great sacro-sciatic foramen, the *posterior* (dorsal) *trunks* of the fourth

and fifth lumbar nerves (lumbo-sacral cord), and of the first and second sacral nerves, combine to form the **peroneal nerve** and the subordinate nerves which arise from the posterior aspect of the plexus. The *anterior* (ventral) *trunks* of the fourth and fifth lumbar nerves (lumbo-sacral cord), and of the first and second sacral nerves, together with that part of the third sacral nerve which is contributed to the plexus, unite to form the **tibial nerve** and the subordinate nerves arising from the front of the plexus.

Of these nerves the fifth lumbar and first sacral are the largest; the others diminishing in size as they are traced upwards and downwards. There is no distinct demarcation between the sacral and pudendal plexuses. The second and third sacral nerves (and in some cases the first sacral also) are concerned in the formation of both plexuses.

Branches.—The nerves of distribution derived from the sacral plexus are thus divided according to their origin into an *anterior* (ventral) and a *posterior* (dorsal) *series.* Each set comprises one of the two essential terminal parts—peroneal and tibial nerves—of the great sciatic, and numerous smaller collateral branches.

Anterior Branches.	**Posterior Branches.**
Tibial (internal popliteal) nerve	Peroneal (external popliteal) nerve
Muscular branches—	*Muscular branches*—
Nerves to hamstring muscles	Nerves to short head of biceps
,, quadratus femoris	,, pyriformis
,, gemelli	Superior gluteal nerve
,, obturator internus	Inferior gluteal nerve
Articular branches (to hip-joint)	*Articular branches* (to knee-joint)

Great Sciatic Nerve.

The **great sciatic nerve** (n. ischiadicus).—It has already been shown how this nerve is formed. It comprises the two main nerves of the sacral plexus, bound together by an investing sheath, which contains, in addition to the peroneal and tibial nerves, a subordinate branch of each, the nerve to the hamstring muscles, from the tibial, and the nerve to the short head of the biceps flexor cruris, from the peroneal nerve. A thick band about half-an-inch in breadth is formed, consisting from within outwards of (1) **nerves to the hamstring muscles**, (2) **tibial** (internal popliteal), (3) **peroneal** (external popliteal), (4) **nerve to short head of the biceps muscle**. The great sciatic nerve extends through the buttock and the back of the thigh. Forming the continuation of the sacral plexus, it enters the buttock by passing through the great sacro-sciatic foramen, in the interval between the pyriformis and superior gemellus. Concealed by the gluteus maximus muscle, it passes downwards to the thigh, accompanied by the sciatic artery, and the comes nervi ischiadici. It lies in the hollow between the great trochanter of the femur and the tuberosity of the ischium, and enters the thigh beneath the fold of the nates and the lower border of the gluteus maximus. At this spot it is comparatively superficial, lying in the angle between the edge of the gluteus maximus above and externally, and the origins of the hamstring muscles internally. In the thigh it is placed upon the adductor magnus beneath the hamstring muscles, and it terminates at a variable point by dividing into the tibial and peroneal nerves. As already stated, these two nerves may be separate from their origins, and their separation may occur at any point between the great sacro-sciatic foramen and the upper part of the popliteal space.

The Nerves of Distribution from the Sacral Plexus.

These are divisible into two series — **collateral** and **terminal branches.** Each subdivision consists of a series of *anterior* (ventral) and *posterior* (dorsal) *trunks.*

Collateral Branches. — The *anterior branches* are (*a*) muscular branches (to the quadratus femoris, gemelli, obturator internus, and hamstring muscles); and (*b*) articular branches (to the hip-joint). These nerves all arise from the anterior aspect of the sacral plexus.

The **nerve to the quadratus femoris** (and inferior gemellus) arises from the front of the fourth and fifth lumbar and first sacral nerves. It passes downwards over the back of the capsule of the hip-joint (to which it sends a fine branch) beneath the sacral plexus, gemelli, and obturator internus muscles. It supplies a nerve to the inferior gemellus, and terminates in the deep surface of the quadratus femoris.

The **nerve to the obturator internus** (and superior gemellus) arises from the anterior aspect of the fifth lumbar and first two sacral nerves. In the buttock it lies below the great sciatic nerve on the outer side of the pudic vessels; crossing the ischial spine, it enters the ischio-rectal fossa through the lesser sciatic foramen. The nerve supplies in the buttock a branch to the superior gemellus, and terminates by entering the pelvic surface of the obturator internus.

The **nerve to the hamstring muscles** forms the innermost part of the great sciatic trunk in the lower part of the buttock. It arises from all the roots of the tibial nerve on their anterior aspect, viz., from the fourth and fifth lumbar and the first three sacral nerves. These roots unite to form a cord which is closely associated with the tibial nerve and is placed in front of and afterwards on its inner side. Extending into the thigh, the trunk is distributed to the hamstring muscles by means of two sets of branches. Just below the level of the ischial tuberosity an upper set of nerves passes inwards to enter the upper part of the semitendinosus and the ischial head of the biceps. Lower down in the thigh the remaining portion of the nerve separates off from the great sciatic (tibial) trunk and supplies branches to the semimembranosus, the lower part of the semitendinosus, and the adductor magnus.

Articular branches for the hip-joint arise from the nerve to the quadratus femoris, and often directly from the front of the great sciatic (tibial) nerve near its origin. They enter the back of the capsule of the joint in the region of the buttock.

The *posterior branches* are: (*a*) muscular branches, viz. a nerve to the pyriformis, the superior gluteal nerve, the inferior gluteal nerve, and a nerve to the short head of the biceps; (*b*) articular branches (to the knee-joint).

These nerves all arise from the back of the roots of the sacral plexus, associated with the origin of the peroneal nerve.

The **nerve to the pyriformis muscle** may be double. It arises from the back of the second, or first and second sacral nerves, and at once enters the anterior surface of the muscle.

The **superior gluteal nerve** (n. glutæus superior) arises from the back of the fourth and fifth lumbar and first sacral nerves, and is directed backwards and outwards into the buttock, above the pyriformis muscle, along with the gluteal artery. Under cover of the gluteus maximus and gluteus medius, it extends outwards over the gluteus minimus, along with the inferior part of the deep gluteal artery, to the under surface of the tensor vaginæ femoris, in which it ends. On its way it supplies branches to the gluteus medius and gluteus minimus.

The **inferior gluteal nerve** (n. glutæus inferior) arises from the back of the fifth lumbar and first two sacral nerves. It appears in the buttock at the lower border of the pyriformis muscle, superficial to the great sciatic nerve, and at once breaks up into a number of branches for the supply of the gluteus maximus. In its course in the buttock it is closely associated with the small sciatic nerve. Its origin is sometimes combined with that of the following nerve.

The **nerve to the short head of the biceps** springs from the outer side of the great sciatic (peroneal) trunk in the upper part of the thigh. When traced to its origin, it is found to arise (sometimes in combination with the inferior gluteal nerve) from the fifth lumbar and first two sacral nerves. In its course it is closely applied to the outer side of the peroneal nerve, from which it separates in the middle third of the thigh, usually in combination with the articular branches of that nerve for the knee-joint. In some cases it has an independent course in the thigh, and it may be associated in the buttock with the inferior gluteal nerve.

An **articular branch** for the outer side and front of the knee-joint generally arises from the great sciatic or peroneal nerve in common with the nerve to the

short head of the biceps. When traced up to the plexus, it is associated with the back of the fourth and fifth lumbar and first sacral nerves. It passes through the upper part of the popliteal space concealed by the biceps muscle, and separates into upper and lower branches, which accompany the upper and lower external articular arteries to the outer side of the knee-joint.

Terminal Branches — The **peroneal** (external popliteal) and **tibial** (internal popliteal) **nerves** are the two main trunks resulting from the combination of the posterior and anterior cords respectively of the sacral plexus. The peroneal nerve is homologous with the musculo-spiral nerve in the upper limb; the tibial nerve represents a medio-ulnar trunk; and as already stated, the two nerves, constituting the great sciatic nerve, are enveloped in a common sheath for a variable distance before beginning an independent course.

Peroneal Nerve.

The **peroneal** or **external popliteal nerve** (n. peronæus communis) arises from the back of the sacral plexus from the fourth and fifth lumbar and first two sacral nerves. Incorporated with the great sciatic nerve in the buttock and upper half of the thigh, it passes downwards from the bifurcation of that nerve through the popliteal space to its termination at a point about an inch below the head of the fibula. It is concealed at first by the biceps muscle. Following the tendon of that muscle, it passes obliquely through the upper and outer part of the popliteal space and over the outer head of the gastrocnemius muscle to the back of the head of the fibula. In the lower part of its course it is directly beneath the deep fascia.

Collateral Branches.—These are divided into two sets: (*a*) Those arising from the roots or trunk of the nerve while it is in combination with the tibial nerve in the great sciatic trunk. These have been already described, viz. a **muscular branch** to the short head of the biceps, and an **articular branch** to the knee-joint. (*b*) Those arising in the popliteal space. These are **cutaneous branches**, viz. a sural branch and the peroneal communicating.

The **sural branch** (n. cutaneus suræ lateralis) is irregular in size and distribution, and may be represented by two or more branches (Fig. 442, p. 603). Arising from the peroneal nerve in the popliteal space, often in common with the succeeding nerve, it pierces the deep fascia over the outer head of the gastrocnemius, and is distributed to the skin on the outer aspect of the back of the leg in the upper two-thirds. The extent of its distribution varies with that of the small sciatic and external saphenous nerves.

The **peroneal communicating nerve** (r. anastomoticus peronæus, r. communicans fibularis), arising in the popliteal space, passes over the outer head of the gastrocnemius beneath the deep fascia to the middle third of the leg, where it assists in forming the external saphenous nerve by its union with the tibial communicating branch of the tibial nerve. In many cases the two branches do not unite. In such cases the peroneal communicating nerve may be limited in its distribution to the skin of the outer side of the leg, heel, and ankle, or it may be distributed to the area usually supplied by the external saphenous nerve.

Terminal Branches.—The terminal branches of the peroneal nerve are recurrent tibial, anterior tibial, and musculo-cutaneous. They arise just below the head of the fibula, and are directed forwards, diverging in their course, beneath the peroneus longus muscle.

The **recurrent tibial nerve** is the smallest branch. Passing forwards beneath the origin of the peroneus longus and the extensor longus digitorum muscles, it divides below the outer tuberosity of the tibia into branches which supply the upper fibres of the tibialis anticus muscle, the tibio-fibular articulations, and the knee-joint.

Anterior Tibial Nerve.

The **anterior tibial nerve** (n. peronæus profundus) passes downwards and inwards, beneath the peroneus longus, extensor longus digitorum, and extensor proprius

hallucis muscles, to the front of the leg. In its course down the leg it is deeply placed upon the interosseous membrane and the lower part of the tibia in company with the anterior tibial artery. At the ankle it lies beneath the anterior annular ligament and the tendon of the extensor proprius hallucis, and crossing over the ankle-joint, it divides on the dorsum of the foot into its terminal branches.

1. **Collateral Branches** (in the leg).—These are given off to the muscles between which the anterior tibial nerve passes: tibialis anticus, extensor proprius hallucis, extensor longus digitorum, and peroneus tertius. A fine articular branch supplies the ankle-joint.

2. **Terminal Branches** (in the foot).—The terminal branches are internal and external. The **internal branch** passes along the dorsum of the foot on the outer side of the dorsalis pedis artery to the first interosseous space, where it divides into two dorsal digital branches for the supply of the skin of the outer side of the great toe and the inner side of the second toe. Each of these branches communicates with branches of the musculo-cutaneous nerve. It gives off one or two *dorsal interosseous branches,* which supply the inner tarso-metatarsal and metatarso-phalangeal articulations, and also enter the first dorsal interosseous muscle.

The **external branch** passes outwards over the tarsus beneath the extensor brevis digitorum, and ends in a gangliform enlargement (similar to the gangliform enlargement on the posterior interosseous nerve at the back of the wrist). From this enlargement muscular branches arise for the supply of the extensor brevis digitorum, along with branches for the tarsal, tarso-metatarsal, and metatarso-phalangeal articulations. Its *dorsal interosseous branches* may be as many as four in number. Of these the outer two, extremely small, may only reach the tarso-metatarsal articulations. The inner two are fine branches, which, besides supplying the articulations, may give branches to the second and third dorsal interosseous muscles.

The branches from the anterior tibial nerve to the interosseous muscles are probably sensory, the motor supply of these muscles being certainly derived from the external plantar nerve.

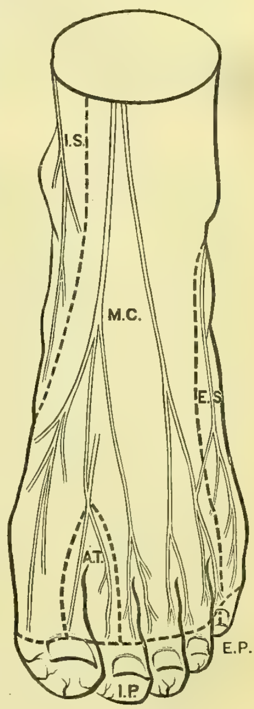


FIG. 443.—DISTRIBUTION OF CUTANEOUS NERVES ON THE DORSUM OF THE FOOT.

I.S, Internal saphenous nerve; M.C, Musculo-cutaneous nerve; A.T, Anterior tibial nerve; E.S, External saphenous nerve. The extremities of the toes are supplied by the plantar nerves (I.P, E.P).

MUSCULO-CUTANEOUS NERVE.

The **musculo-cutaneous nerve** (n. peronæus superficialis), the last of the branches of the peroneal nerve, passes below the head of the fibula and beneath the upper fibres of the peroneus longus muscle. Lying in a sheath in the intermuscular septum, between the peronei externally and the extensor longus digitorum internally, it proceeds downwards in front of the fibula to the lower third of the leg, where it pierces the deep fascia in two branches, internal and external.

Its branches are: (1) collateral muscular branches distributed to the peronei muscles, longus and brevis, as the nerve lies in relation to them; (2) terminal cutaneous branches, internal and external.

The **internal terminal branch** courses downwards over the anterior annular ligament of the ankle, and after supplying offsets to the lower third of the leg and dorsum of the foot, divides into three branches. (1) The most internal supplies the skin of the dorsum of the foot and the inner side of the great toe, and communicates with the internal saphenous nerve. (2) The middle branch passes to the interval between the great toe and the second, and divides into two branches which communicate with the internal branch of the anterior tibial nerve. (3) The external branch passes to the interval between the second and third toes, and divides into two digital branches to supply the adjacent sides of these toes.

The **external terminal branch** of the musculo-cutaneous nerve descends over the anterior annular ligament, and after supplying branches to the lower part of the leg and the dorsum of the foot, divides into two parts, internal and external, which, passing to the intervals between the third and fourth, and fourth and fifth toes respectively, divide into dorsal digital branches for the adjacent sides of these toes. These branches communicate with offsets of the external saphenous nerve.

The arrangement of the cutaneous branches of the musculo-cutaneous is liable to considerable variation. The nerve to the adjacent sides of the second and third toes may come from the outer division of the nerve, which, again, is not unfrequently much reduced in size, in which case the external saphenous nerve takes its place on the dorsum of the foot, often supplying as many as two and a half toes on the outer side.

The cutaneous nerves on the dorsum of the toes from the anterior tibial and musculo-cutaneous nerves are much smaller than the corresponding plantar digital nerves. They are reinforced on the dorsum of the terminal phalanges by twigs from the plantar nerves, which supply the tips of the toes and nails.

Tibial Nerve.

The **tibial** or **internal popliteal nerve** (n. tibialis) arises from the front of the sacral plexus, usually from the fourth and fifth lumbar and first three sacral nerves (Fig. 446, p. 614). It is incorporated in the great sciatic trunk in the buttock and upper part of the thigh. At the bifurcation of this nerve it passes directly downwards through the popliteal space, and enters the back of the leg at the lower border of the popliteus muscle. The part of the nerve from its origin from the plexus or the bifurcation of the great sciatic nerve to the lower border of the popliteus muscle is sometimes called **internal popliteal**; the part of the nerve in the back of the leg being then designated **posterior tibial.** In the popliteal space it is concealed at first by the semimembranosus and other hamstring muscles. It afterwards lies beneath the gastrocnemius and plantaris muscles, and in its course it crosses the popliteal vessels from without inwards, so as to lie below upon the popliteus muscle. In the back of the leg, from the lower border of the popliteus muscle to the ankle, the tibial (or posterior tibial) nerve lies on the tibialis posticus muscle and the tibia, and, along with the posterior tibial vessels, occupies a sheath in the intermuscular septum separating the superficial and deep muscles of the back of the leg. In the upper part of the leg it is internal to the vessels, but, crossing over them, it lies on their outer side in the lower portion of its course. The nerve terminates beneath the internal annular ligament by dividing into the external and internal plantar nerves.

The **collateral branches** may be divided into three sets:—

(a) *Branches arising from the Roots or Trunk of the Nerve while it is incorporated with the Great Sciatic Nerve.*—These have been already described, viz. **muscular branches** to the quadratus femoris, gemelli, obturator internus, and the hamstring muscles, and an **articular branch** to the hip-joint (Fig. 446, p. 614).

(b) *Branches arising in the Popliteal Space above the Knee-Joint.*—These are in three sets—articular, muscular, cutaneous.

1. The **articular branches** are slender nerves, variable in number. There are usually two, an azygos branch which pierces the posterior ligament of the knee joint, and an internal branch, a long fine nerve which, crossing the popliteal vessels, descends on the inner side of the space to accompany the lower internal articular artery to the knee-joint. In its course it gives off a branch which accompanies the upper internal articular artery. It is often absent.

2. The **muscular branches** are five in number. Nerves for the two heads of the gastrocnemius and plantaris enter the muscles at the borders of the popliteal space. A nerve for the soleus enters the superficial surface of the muscle. A nerve for the popliteus muscle passes over the surface of that muscle, and after winding round its lower border, supplies it on its deep (anterior) surface. As this nerve passes beneath the popliteus it supplies branches to the tibialis posticus muscle, an interosseous branch for the interosseous membrane, which can be traced as far as the lower tibio-fibular articulation, an articular branch for the upper tibio-fibular joint, and a medullary branch for the shaft of the tibia.

3. The **cutaneous branch** is the **tibial communicating nerve** (n. communicans

tibialis, n. cutaneus suræ medialis). This nerve passes from the popliteal space in the groove between the two heads of the gastrocnemius muscle, and afterwards lies upon the tendo achillis. It pierces the deep fascia in the middle third of the back of the leg, and is joined immediately afterwards by the peroneal communicating nerve from the peroneal nerve. From their union the **external or short saphenous nerve** results, which reaches the foot, winding round the back of the external malleolus along with the external saphenous vein. The external saphenous nerve supplies cutaneous branches to the outer side and back of the lower third of the leg, the ankle and heel, and the outer side of the foot and little toe, as well as articular branches to the ankle and tarsal joints.

The external saphenous nerve communicates on the foot with the musculo-cutaneous nerve, and its size varies with the size of that nerve. It may extend on to the dorsum of the foot for a considerable distance, and may either reinforce or replace the branches of the musculo-cutaneous nerve to the intervals between the fourth and fifth and even the third and fourth toes. The mode of formation of the external saphenous nerve is very variable. The usual arrangement is that described. Frequently the peroneal and tibial communicating nerves do not unite, and in such cases the more usual arrangement is for the tibial communicating nerve to form alone the external saphenous nerve, the peroneal communicating nerve extending only to the ankle and heel. It is less usual for the peroneal communicating nerve to form alone the external saphenous nerve, the tibial communicating nerve in these cases ending at the heel.

(c) *Branches arising in the Back of the Leg below the Knee-Joint.*—These branches are mainly muscular and cutaneous.

The **muscular branches** are four in number, comprising nerves to the soleus (entering its deep surface) and tibialis posticus, often arising by a common trunk, and nerves to the flexor longus digitorum and flexor longus hallucis, the latter generally accompanying the peroneal artery for some distance.

The **cutaneous branch** is the **internal calcanean nerve** (rr. calcanei mediales), which pierces the internal annular ligament, and is distributed to the skin of the heel and back part of the sole of the foot.

In addition a medullary nerve to the fibula, and a small articular branch to the ankle-joint, are supplied by the posterior tibial nerve.

The **terminal branches of the tibial nerve** are the internal and external plantar nerves.

Internal Plantar Nerve.

The **internal plantar nerve** (n. plantaris medialis) is homologous with the median nerve in the hand (Fig. 445, p. 612). It is rather larger than the external plantar. It courses forwards in the sole of the foot

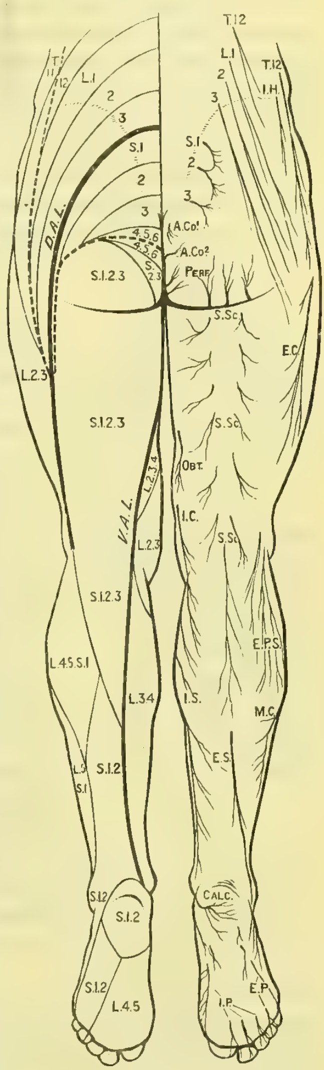


Fig. 444.—Distribution of Cutaneous Nerves on the Back of the Lower Limb.

On the one side the distribution of the several nerves is represented the letters indicating their nomenclature.

L.1, 2, 3, S.1, 2, 3, Posterior primary divisions of lumbar and sacral nerves; I.H, Ilio-hypogastric; T.12, Lateral and posterior branches of last thoracic nerve; A.Co¹, Posterior sacro-coccygeal nerve ; A.Co², Anterior sacro-coccygeal nerve ; Perf, Perforating cutaneous nerve ; S.Sc, Small sciatic ; E.C, External cutaneous ; Obt, Obturator ; I.C, Internal cutaneous ; E.P.S, Sural branches of peroneal ; I.S, Internal saphenous ; E.S, External saphenous ; M.C, Musculo-cutaneous ; Calc, Calcanean branch of posterior tibial ; I.P, Internal plantar ; E.P, External plantar nerve.

On the other side a schematic representation is given of the areas supplied by the above nerves, the letters indicating the spinal origin of the branches of distribution to each area.

beneath the internal annular ligament and abductor hallucis to the interval between that muscle and the flexor brevis digitorum, in company with the internal plantar artery.

The **collateral branches** are muscular, cutaneous, and articular. The muscular branches supply the abductor hallucis and the flexor brevis digitorum. The plantar cutaneous branches are small twigs which pierce the plantar fascia in the interval between these muscles to supply the inner part of the sole of the foot. The articular branches are minute twigs which supply the inner tarsal and tarso-metatarsal articulations.

The **terminal branches** are four in number, and may be designated first, second, third, and fourth, from within outwards.

The **first** (most internal) branch separates from the nerve before the others, and pierces the plantar fascia behind the ball of the great toe. It supplies a muscular branch to the flexor brevis hallucis, and cutaneous branches to the inner side of the foot and ball of the great toe. It terminates as the plantar digital nerve for the inner side of the great toe.

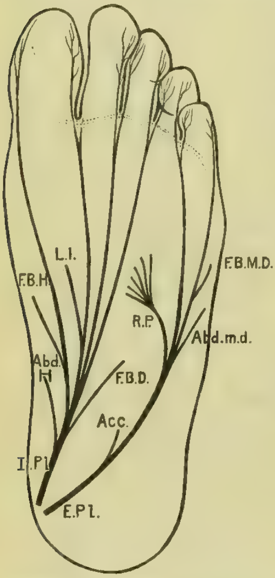


Fig. 445.—Scheme of Distribution of the Plantar Nerves.

I.Pl, Internal plantar nerve, and its cutaneous and muscular branches ; F.B.D, Flexor brevis digitorum ; Abd.H, Abductor hallucis ; F.B.H, Flexor brevis hallucis ; L.I, First lumbricalis ; E.Pl, External plantar nerve, and its cutaneous and muscular branches ; Acc, Accessorius ; Abd.m.d, Abductor minimi digiti ; F.B.M.D, Flexor brevis minimi digiti ; R.P, Ramus profundus.

The **second branch** arises along with the third and fourth ; after supplying a branch to the first lumbrical muscle, it becomes superficial in the interval between the first and second toes, and terminates by dividing into two plantar digital nerves for the supply of the adjacent sides of these toes.

The **third** and **fourth branches** are entirely cutaneous in their distribution. They become superficial in the intervals between the second and third and the third and fourth toes respectively, and there divide into plantar digital branches for the supply of the adjacent sides of these toes.

The **plantar digital nerves** supply the whole length of the toes on the plantar aspect, and, in relation to the terminal phalanges, furnish minute dorsal offsets for the supply of the nails and tips of the toes on their dorsal surface. The internal plantar nerve thus supplies the skin of the three and a half inner toes in the sole of the foot and four muscles : the abductor hallucis and flexor brevis digitorum, the flexor brevis hallucis, and the first lumbrical muscle.

External Plantar Nerve.

The **external plantar nerve** (n. plantaris lateralis) is homologous with the ulnar nerve in the hand. From its origin beneath the internal annular ligament it extends forwards and outwards in the sole, in company with the external plantar artery, between the flexor brevis digitorum and accessorius muscles, towards the head of the fifth metatarsal bone. Here it terminates by dividing into superficial and deep branches.

Collateral Branches.—*Muscular branches* are given off from the undivided nerve to the accessorius and abductor minimi digiti muscles. *Cutaneous branches* pierce the plantar fascia at intervals along the line of the intermuscular septum, between the flexor brevis digitorum and abductor minimi digiti.

Terminal Branches.—The **superficial branch** (r. superficialis) is mainly cutaneous. Passing forwards between the flexor brevis digitorum and abductor minimi digiti, it divides into external and internal parts.

The *external branch*, after supplying the flexor brevis minimi digiti muscle, and sometimes one or both interossei of the fourth space, becomes superficial behind the ball of the little toe, and supplies cutaneous twigs to the sole of the foot and ball of the toe. It terminates as the plantar digital branch for the outer side of the little toe.

The *internal branch* passes forwards to the interval between the fourth and fifth toes, where it becomes cutaneous, and divides into two plantar digital branches for the supply of the adjacent sides of these toes. It communicates with the fourth terminal branch of the internal plantar nerve.

The **deep branch** (r. profundus) of the external plantar nerve, passing deeply along with the external plantar artery, extends inwards towards the great toe, beneath the accessorius and adductor obliquus hallucis. It gives off *articular branches* to the tarsal and tarso-metatarsal articulations, and *muscular branches* to the interossei of each space (except in some cases the muscles of the fourth space): the adductor obliquus and adductor transversus hallucis, and the outer three lumbrical muscles. These nerves enter the deep surface of the muscles, that to the second lumbrical reaching its muscle after passing forwards beneath the adductor transversus hallucis.

THE PUDENDAL PLEXUS.

The pudendal plexus constitutes the third and last subdivision of the lumbo-sacral plexus. It is composed for the most part of the spinal nerves below those which form the sacral plexus; but, as already stated, there is no distinct point of separation between the two plexuses. On the contrary, there is considerable over-lapping, so that two and sometimes three of the principal nerves derived from the pudendal plexus have their origin in common with nerves of the sacral plexus.

The plexus is formed by fibres from the anterior primary divisions of the first three sacral nerves, and by the whole of the anterior primary divisions of the fourth and fifth sacral and coccygeal nerves. The size of the nerves diminishes rapidly from the first sacral to the coccygeal, which is extremely slender.

Position and Constitution.—The plexus is formed on the back wall of the pelvis. Of the nerves forming it, the upper ones emerge from the anterior sacral foramina; the fifth sacral nerve appears between the last sacral and first coccygeal vertebra; and the coccygeal nerve appears below the transverse process of that vertebra. The nerves of distribution derived from the plexus are the following:—

1. Visceral branches.
2. Small sciatic nerve.
3. Perforating cutaneous nerve.
4. Pudic nerve.
5. Muscular branches.
6. Sacro-coccygeal nerve.

Omitting the visceral branch, all the nerves are distributed to the perineum. Only two, the small sciatic and perforating cutaneous nerves, send branches to the lower limb.

Visceral Branches.—Like the other spinal nerves, the fourth and fifth sacral and coccygeal nerves are provided with fine *gray rami communicantes* from the sacral gangliated cord, which joins them after a short course on the front of the sacrum. The third (along with the second or fourth) sacral nerve in addition sends a considerable *white ramus communicans* or **visceral branch** inwards to the pelvic plexus and viscera.

Small Sciatic Nerve (n. cutaneus femoris posterior).—This nerve is complex both in origin and distribution (Fig. 446, p. 614). Springing from the junction of the sacral and pudendal plexuses, it is derived from the first three sacral nerves. It is distributed to both the lower limb and perineum, and is associated with other nerves belonging to both regions. It arises from the back of the roots of the sacral plexus in the pelvis. Its higher roots from the first and second sacral nerves are intimately associated with the origin of the inferior gluteal nerve; its lowest root from the third sacral nerve is associated with the origins of the perforating cutaneous or pudic nerve. It enters the buttock through the great sciatic notch below the pyriformis, along with the sciatic artery and inferior gluteal nerve. Proceeding downwards behind the great sciatic nerve, it enters the thigh at the lower border of the gluteus maximus muscle, where it gives off considerable branches. Becoming gradually smaller as it courses downwards over the hamstring muscles to the popliteal space, it finally pierces the popliteal fascia in one or more cutaneous branches, which supply the skin over the calf of the leg for a variable distance (Fig. 444, p. 611).

Branches.—The small sciatic is a purely cutaneous nerve. It supplies branches to the perineum, buttock, thigh, and leg.

The **perineal branch** (rr. perinæales; inferior pudendal nerve; long scrotal

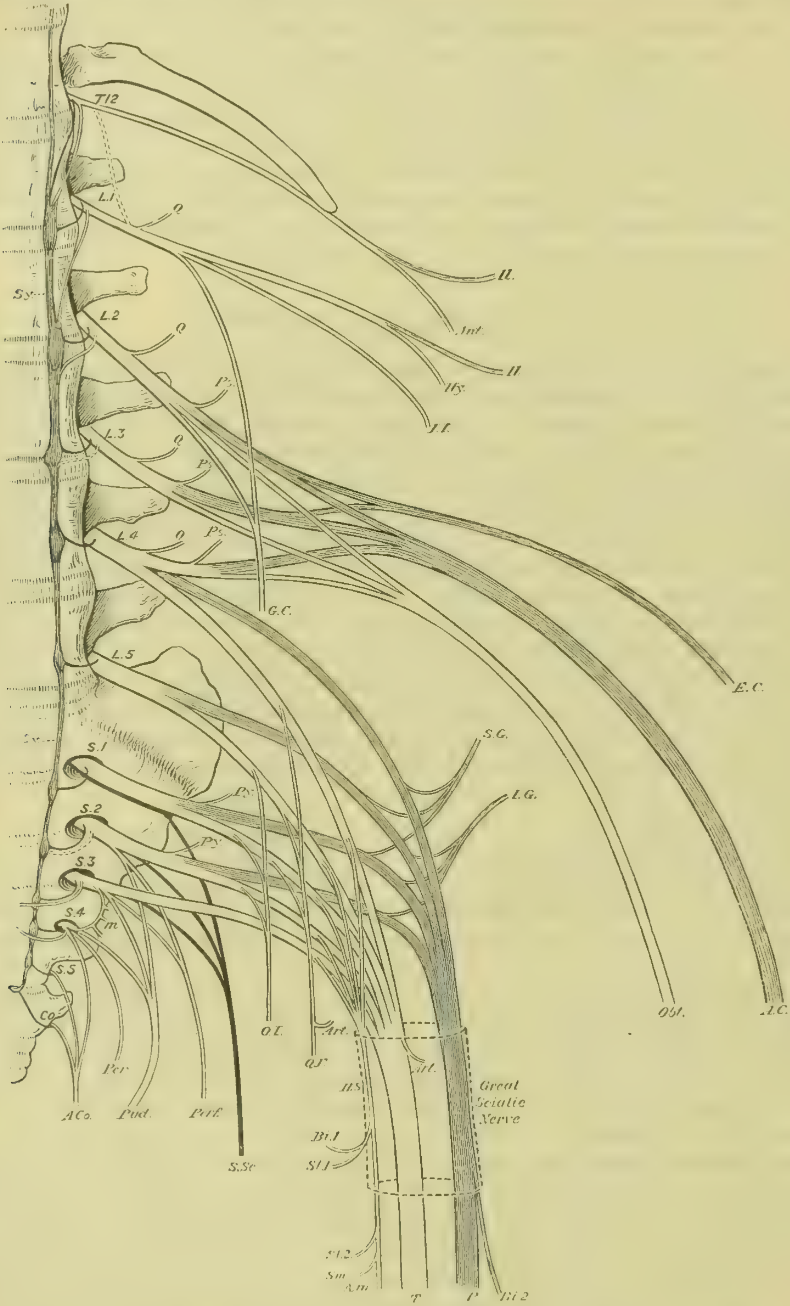


FIG. 446.—NERVES OF THE LUMBO-SACRAL PLEXUS.

Sy, Sympathetic cord; T.12, L.1, 2, 3, 4, 5, S.1, 2, 3, 4, 5, Co, Anterior primary divisions of the last thoracic, the lumbar, sacral, and coccygeal nerves; Q, Nerves to quadratus lumborum; Ps, Nerves to psoas muscle; G.C, Genito-crural nerve; Il, Iliac branches of last thoracic and ilio-hypogastric nerves; Hy, Hypogastric branch of ilio-hypogastric nerve; I.I, Ilio-inguinal nerve; E.C, External cutaneous nerve; A.C, Anterior crural nerve; Obt, Obturator nerve; Py, Nerves to pyriformis muscle; O.I, Nerve to obturator internus; Q.F, Nerve to quadratus femoris muscle; Art, Articular branch; S.G, Superior gluteal nerve; I.G, Inferior gluteal nerve; P, Peroneal nerve; Bi.2, Nerve to short head of biceps muscle; T, Tibial nerve; Art, Articular branch; H.S, Nerve to the hamstring muscles; Bi.1, Nerves to biceps (long head), and St.1, to semitendinosus; St.2, Semitendinosus; Sm, Semimembranosus; A.m, Adductor magnus; S.Sc, Small sciatic nerve; Perf, Perforating cutaneous nerve; Pud, Pudic nerve; M, Muscular branches; Per, Perineal branch of fourth sacral; A.Co, Anterior sacro-coccygeal nerve.

nerve) arises from the small sciatic nerve at the lower border of the gluteus maximus muscle (Fig. 447, p. 616). It sweeps inwards towards the perineum, lying on the origin of the hamstring muscles below the ischial tuberosity, and terminates by becoming subcutaneous over the pubic arch. Its terminal branches supply the skin of the scrotum and root of the penis, or in the female the labium majus and clitoris, some of them being directed backwards towards the anus and central point of the perineum. They communicate with the inferior hæmorrhoidal and perineal branches of the pudic nerve and with the ilio-inguinal nerve. In its course to the perineum the nerve gives off *collateral branches* to the skin of the upper and inner part of the thigh.

The **gluteal branches** (rr. clunium inferiores) are large and numerous (Fig. 444, p. 611). They arise from the small sciatic nerve beneath the gluteus maximus, and become subcutaneous by piercing the fascia lata at different points along its lower border. They supply the skin of the lower half of the buttock. The outermost branches, reaching to the back of the great trochanter, overlap the terminal filaments of the gluteal branches of the external cutaneous nerve, and the posterior primary divisions of the first three lumbar nerves. The innermost branches, which may pierce the great sacro-sciatic ligament, reach nearly to the coccyx, and are coterminous in their distribution with the branches of the perforating cutaneous nerve, which they reinforce and not unfrequently replace.

The **femoral branches** are divisible into two sets—*internal* and *external*. They pierce the fascia lata of the thigh at intervals, and respectively supply the skin of the back of the thigh on its inner and outer sides.

The **sural branches** are two or more slender nerves which pierce the fascia over the popliteal space, and are distributed for a variable extent to the skin of the back of the leg. They may stop short over the popliteal space, or may extend as far as the ankle. Usually they innervate the skin as far as the middle of the calf. They communicate with the external saphenous nerve.

In cases where the great sciatic nerve is naturally divided at its origin into tibial (internal popliteal) and peroneal (external popliteal) nerves (*e.g.* by the pyriformis muscle), the small sciatic nerve is also separated into two parts: a **dorsal part**, associated with the peroneal nerve and arising in common with the lower roots of the inferior gluteal nerve (usually from the first and second sacral nerves), which comprises the gluteal and external femoral branches; and a **ventral part**, associated with the tibial nerve and arising usually from the second and third sacral nerves, along with the perforating cutaneous and pudic nerves, which comprises the perineal and internal femoral branches.

Perforating Cutaneous Nerve (n. perforans ligamenti tuberoso-sacri (Schwalbe), n. cutaneus clunium inferior medialis (Eisler)).—This nerve arises from the back of the second and third sacral nerves (Fig. 447, p. 616). It is associated at its origin with the lower roots of the small sciatic nerve. Passing downwards it pierces the great sacro-sciatic ligament, along with the coccygeal branch of the sciatic artery; and after winding round the lower border of the gluteus maximus muscle, or piercing its lower fibres, it becomes subcutaneous a little distance from the coccyx, and supplies the skin over the lower part of the buttock and the inner part of the fold of the nates.

The perforating cutaneous nerve is not always present. In a minority of cases it is associated at its origin with the pudic nerve. When absent as a separate nerve, its place is taken by (1) gluteal branches of the small sciatic nerve, or (2) a branch from the pudic nerve, or (3) a small nerve (n. perforans coccygeus major, Eisler), arising separately from the back of the third and fourth sacral nerves.

Muscular Branches.—Between the third and fourth sacral nerves (occasionally reinforced by the second, Eisler) a plexiform loop is formed, from which muscular nerves are given off to the levator ani (supplying the muscle on its pelvic surface), coccygeus, and external sphincter. The nerve to the external sphincter (*perineal branch of fourth sacral*) pierces the great sacro-sciatic ligament and the coccygeus muscle, to which it gives offsets, and appears in the ischio-rectal fossa between the gluteus maximus and the external sphincter. Besides supplying the posterior fibres of the external sphincter, it distributes cutaneous offsets to the skin

of the ischio-rectal fossa and the fold of the nates behind the anus. This nerve replaces, in some cases, the perforating cutaneous nerve.

Anterior Sacro-coccygeal Nerves (nn. ano-coccygei).—By the union of the remaining part of the fourth with the fifth sacral and coccygeal nerves, the so-called **coccygeal plexus** is formed. A fine descending branch of the fourth sacral nerve passes over or through the great sacro-sciatic ligament, to join the fifth sacral nerve. This fifth sacral nerve, joined by the descending branch of the fourth, descends alongside the coccyx and is again joined by the coccygeal nerve, so that a plexiform cord results, homologous with the inferior caudal trunk of tailed animals. Fine twigs arise from it, which pierce the sacro-sciatic ligament and supply the skin in the neighbourhood of the coccyx, internal to the perforating cutaneous nerves and behind the anus.

The Pudic Nerve.

The **pudic nerve** (n. pudendus) is the principal nerve for the supply of the perineum. It arises in the pelvis usually by three roots from the second, third, and fourth sacral nerves (Fig. 446, p. 614). (Frequently one of its branches, the inferior hæmorrhoidal nerve, arises independently from the third and fourth sacral nerves.)

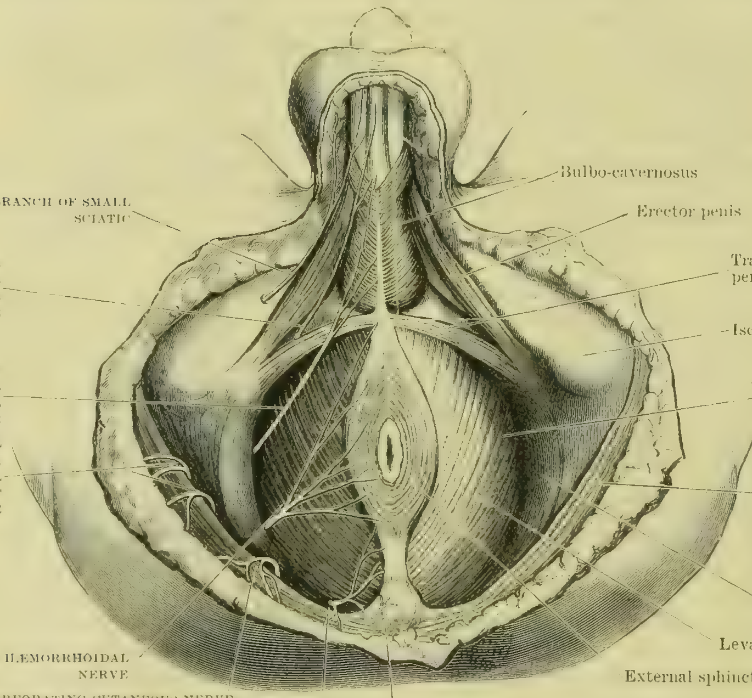


Fig. 447.—The Muscles and Nerves of the Male Perineum.

The nerve passes to the buttock through the great sacro-sciatic foramen below the great sciatic nerve, and lies on the lesser sacro-sciatic ligament, or the spine of the ischium, internal to the internal pudic artery. It enters the perineum along with the pudic artery through the small sacro-sciatic foramen. In the perineum it is deeply placed in the outer wall of the ischio-rectal fossa, enclosed in a special sheath derived from the parietal pelvic fascia covering the inner surface of the obturator internus muscle. At the anterior limit of the ischio-rectal fossa, the nerve approaches the surface and divides at the base of the triangular ligament into its terminal branches, the perineal nerve and the dorsal nerve of the penis.

The branches of the pudic nerve are essentially the same in the two sexes. As a rule no branches are given off till the nerve enters the perineum, but sometimes the inferior hæmorrhoidal nerve has an independent origin from the

plexus, merely accompanying the pudic nerve in the first part of its course; in exceptional cases the perforating cutaneous nerve of the buttock is a branch of the pudic nerve.

The **inferior hæmorrhoidal nerve** (n. hæmorrhoidalis inferior) arises from the pudic nerve under cover of the gluteus maximus, at the posterior part of the ischio-rectal fossa. In cases in which it has an independent origin from the plexus, it arises from the third and fourth sacral nerves. It crosses the ischio-rectal fossa in company with the inferior hæmorrhoidal vessels and separates into numerous branches—muscular, cutaneous, and communicating.

The **muscular branches** end in the external sphincter muscle. The **cutaneous branches** supply the skin around the anus. The **communicating branches** connect the inferior hæmorrhoidal with three other nerves—the perineal branches of the small sciatic, pudic, and fourth sacral nerves.

The **perineal nerve** (n. perineus), one of the two terminal branches of the pudic nerve, arises near the base of the triangular ligament. It almost immediately divides into two parts, superficial and deep.

The **superficial part** is purely cutaneous and consists of two nerves, the posterior or external and the anterior or internal superficial perineal nerves, which pass, along with the superficial perineal vessels, to the anterior part of the perineum.

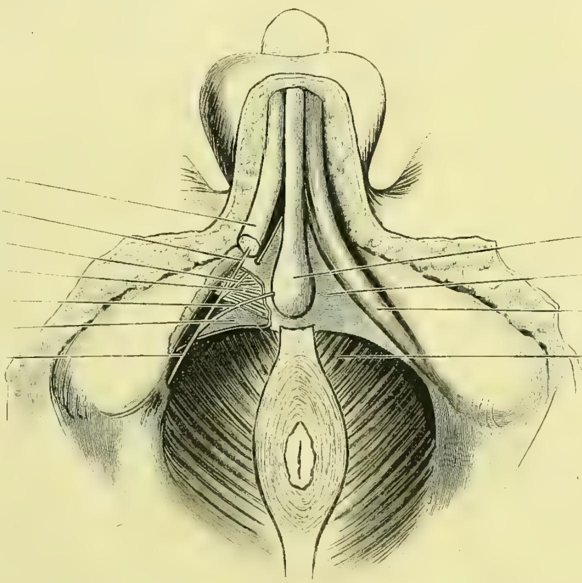


Fig. 448.—The Triangular Ligament of the Perineum.

The **posterior or external superficial perineal nerve**, at the anterior limit of the ischio-rectal fossa, usually passes over the base of the triangular ligament and the transversus perinei muscle. The **anterior or internal superficial perineal nerve**, lying more deeply, pierces the base of the triangular ligament and goes underneath or through the transversus perinei muscle. Becoming superficial in the anterior (urethral) triangle of the perineum, they are distributed to the skin of the scrotum (or labium majus), and communicate with the perineal branch of the small sciatic nerve and with the inferior hæmorrhoidal nerve.

The **deep part** of the perineal nerve is mainly but not entirely muscular. Coursing forwards through the anterior part of the ischio-rectal fossa, it passes between the two layers of the triangular ligament towards the urethra. It supplies muscular branches to the anterior parts of the levator ani and external sphincter, to the transversus perinei, erector penis (or clitoridis), bulbo-cavernosus (ejaculator urinæ or sphincter vaginæ), and compressor urethræ. It terminates as the nerve to the bulb, which, piercing the triangular ligament, enters the bulb of the urethra and supplies the erectile tissue of the bulb and corpus spongiosum, as well as the mucous membrane of the urethra as far as the glans penis (or clitoridis).

The **dorsal nerve of the penis**, the other terminal branch of the pudic nerve, accompanies the internal pudic artery beneath the superficial layer of the triangular ligament. It passes forward close to the pubic arch, lying beneath the crus and erector penis (or clitoridis), and triangular ligament, and upon the compressor urethræ muscle; piercing the triangular ligament near its apex, at the outer side of the dorsal artery of the penis (or clitoris), it passes on to the dorsum of the penis or clitoris, to which it is distributed in its distal two-thirds, sending branches round the sides of the organ to reach its under surface. In the female the nerve is much smaller than in the male. The dorsal nerve of the penis supplies one branch, the **nerve to the corpus cavernosum,** as it lies beneath the triangular ligament. This is a slender nerve, which, piercing the triangular ligament, supplies the erectile tissue of the crus and corpus cavernosum.

Morphology of the Pudendal Plexus.—The structures occupying the perineum are placed in the ventral axis of the body, and comprise from above downwards the penis and scrotum, or mons Veneris and vulva, the central point of the perineum, the anus and ischio-rectal fossa, and the coccyx. They are placed on the inner side of the attachment of the lower limbs—the penis or mons Veneris in relation to the preaxial border; the coccyx in relation to the postaxial border of the limb.

The nerves of the perineum, thus reaching the ventral axis of the trunk, are homologous with the anterior (ventral) terminations of other nerves. They are separated into two series. Mainly supplied through the pudendal plexus by the last four sacral and the coccygeal nerves, the perineum is also innervated to a minor extent by the first lumbar nerve through the ilio-inguinal nerve, which reaches the root of the penis and the scrotum. The perineum is thus supplied by two series of widely separated nerves, which have their meeting-place on the dorsum and side of the penis and scrotum. This junction of the ilio-inguinal and pudendal nerves constitutes the beginning of the **ventral axial area or line,** which extends peripherally down the inner side of the lower limb. Apart from this break in their distribution, a definite numerical order may be followed in the arrangement of the perineal nerves. The higher parts of the perineum are innervated by the higher spinal nerves; the lower parts, by the lower nerves. This is best exemplified in the distribution of the cutaneous nerves. The base of the penis and scrotum (or mons Veneris) is supplied by the first lumbar nerve (ilio-inguinal). The dorsal nerve of the penis (or clitoris), when traced back to the pudendal plexus, is found to come from the second, and to a less extent from the third sacral nerves; the scrotal nerves (perineal branches of the pudic and small sciatic) similarly arise from the third, and to a less extent from the second sacral nerves; the skin of the ischio-rectal fossa and anus is innervated by the inferior hæmorrhoidal (third and fourth sacral nerves), and the perineal branch of the fourth sacral nerve. The coccygeal plexus, lastly, supplies the skin round the coccyx (fourth and fifth sacral and coccygeal nerves). Judged from its nerve supply the perineum is to be regarded as occupying, for the most part, a position below or more caudal than that of the lower limb in relation to the trunk. There is here a remarkable gap in the numerical sequence of the nerves supplying the ventral axis of the body. All the nerves between the first lumbar and the second sacral fail to reach the middle line of the trunk anteriorly and are wholly concerned in the innervation of the lower limb.

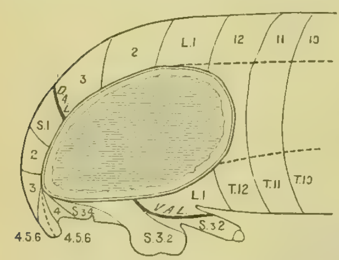


FIG. 449.—SCHEME of the innervation of the hinder portion of the trunk and of the perineum, and the interruption of the segmental arrangement of the nerves associated with the formation of the limb.

T.10, 11, 12, The areas of distribution of the lower thoracic nerves; L.1, 2, 3, The posterior primary divisions of the first three lumbar nerves; L.1, The ilio-inguinal nerve; S.1, 2, 3, 4, 5, 6, The posterior primary divisions of the sacral and coccygeal nerves (6); S.3, 2, S.3, 2, Branches of pudic nerve to penis and scrotum; S.3, 4, Inferior hæmorrhoidal nerve; 4, Perineal branch of the fourth sacral nerve; 4, 5, 6, Anterior sacrococcygeal nerve; D.A.L, Dorsal axial line; V.A.L, Ventral axial line.

At the preaxial border of the limb (groin) the first lumbar nerve, the highest nerve supplying the perineum, is concerned also in innervating the skin of the limb. At the postaxial border of the limb (fold of the nates and back of the thigh), the nerves which are the highest of those constituting the pudendal plexus (the second and third sacral nerves) are also implicated in innervating that border of the limb. The fourth sacral nerve is only concerned to a very slight extent in the innervation of the limb by means of the perineal branch, which reaches the beginning of its postaxial border; the last two spinal nerves are wholly unrepresented in the limb proper and end entirely in the trunk below the limb.

DEVELOPMENT OF THE SPINAL NERVES.

I. **Origin of the Spinal Nerve Roots.**—The process of development of the spinal nerves commences by means of the outgrowth of the **dorsal** and **ventral roots** from the medullary tube. The two roots take origin in quite different ways.

The **dorsal root** is the first to appear,—before, during, or after the union of the medullary plates and the formation of the neural tube. It takes origin as a **cellular bud** from the dorsal surface of the medullary tube in one of three ways:—(1) It may arise from the junction of the medullary plate and surface epiblast before the closure of the medullary groove. (2) It may spring from the *neural crest*, a ridge on the dorsal aspect of the medullary tube, after its closure is complete. (3) It may be simply a direct outgrowth from the dorsal surface of the medullary tube. Pyriform in shape, the bud enlarges and becomes separated from the medullary tube, and projects ventrally in the space between the myotome and the medullary tube. Each bud is separated by only a slight interval from its neighbour.

The cells (**neuroblasts**) composing the bud become rapidly spindle-shaped, and by the middle of the fourth week give rise to *two sets of processes*; (1) a **central series**, which

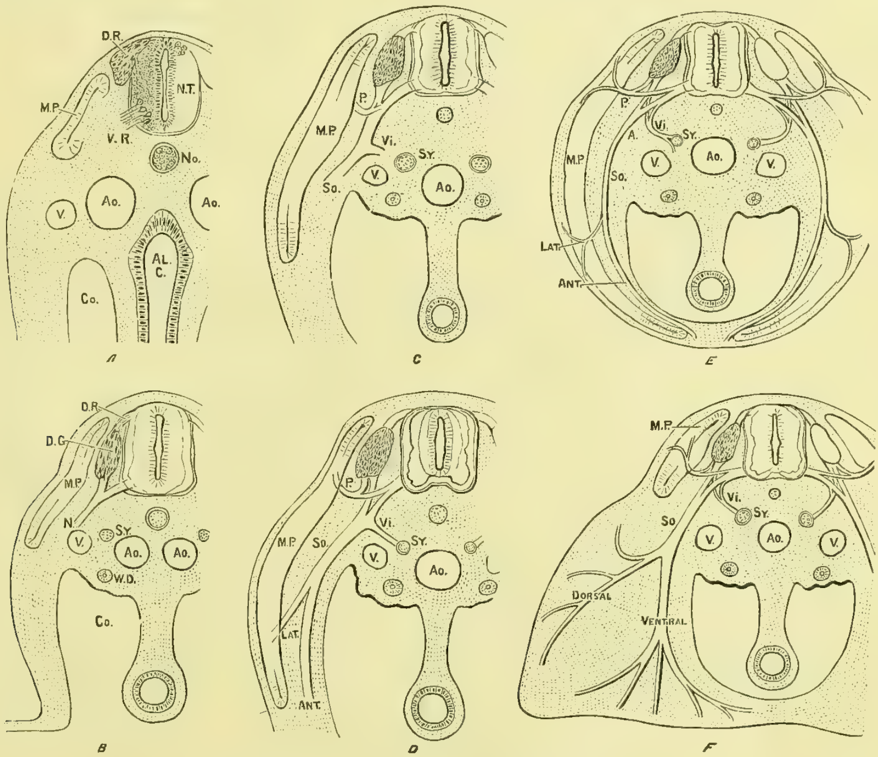


FIG. 450.—DEVELOPMENT OF THE SPINAL NERVES.

A, Formation of nerve roots.

D.R, Dorsal root.
V.R, Ventral root.
N.T, Neural tube.
No, Notochord.

Al.C, Alimentary canal.
Ao, Aorta.
V, Cardinal vein.
M.P, Muscle plate.

B, Formation of nerve trunk (N).

D.G, Dorsal ganglion.
Sy, Sympathetic cord.
W.D, Wolffian duct.
Co, Cœlom.

C, Formation of nerves.

So, Somatic division.
Vi, Visceral branch.
P, Posterior primary division.

D, E, Formation of subordinate branches.

Lat, Lateral, and
Ant, Anterior, branches.

F, Formation of nerve trunks in relation to the limb: dorsal and ventral trunks corresponding to lateral and anterior trunks in D. and E.

grow backwards and are secondarily connected with the dorso-lateral aspect of the medullary tube as the fibres of the dorsal root; and (2) a **peripheral series**, which constitute the dorsal root fibres of the spinal nerve and join the ventral root, to form the spinal nerve proper. The intermediate cellular mass remains as the **spinal ganglion**.

The **ventral root** of a spinal nerve arises in quite a different way, from cells (**neuroblasts**) in the substance of the medullary tube. In the account of the development of the spinal cord it has been shown how the cellular constituents of the medullary tube are converted into two classes of cells: (1) **spongioblasts**, which produce the matrix (neuroglia) of the spinal cord; and (2) **germ-cells** or **neuroblasts**, which produce the nerve-cells of the gray matter of the cord. The neuroblasts give rise to the axis-cylinder processes or **axons**, which, penetrating the spongy tissue of the medullary tube and the outer limiting

membrane, find their way into the mesoblastic tissue on the ventro-lateral surface of the tube. Fibrous from their earliest origin and derived from nerve-cells which remain within the medullary tube, the axons of which the ventral root is composed become surrounded by mesoblastic cells immediately on their emergence, which give rise to the sheaths of the nerve. The ventral root is a little later in its date of appearance than the dorsal root. It begins to be evident at the twenty-fourth day and is completely formed by the twenty-eighth day.

II. **Formation of the Spinal Nerve.**—The fibres of the dorsal root ganglion and the ventral root grow by extension from the cells with which they are respectively connected, and meet in the space between the myotome and the side of the medullary tube to form the **spinal nerve**. It has been already shown that in the adult there is a fundamental division of the spinal nerve into posterior and anterior primary divisions. In the process of development this separation is even more obvious. As the fibres of the dorsal and ventral roots approximate, they separate at the same time each into two unequal portions: the smaller parts of the two roots unite together to form the **posterior**, and the larger parts unite to form the **anterior primary division** of the spinal nerve.

The **posterior primary division**, curving outwards and dorsally, passes through the myotome and is connected with it. In the substance of the myotome it separates into branches as it proceeds towards the dorsal wall of the embryo. At a later stage, the branches are definitely arranged into an outer and an inner set.

The **anterior primary division** grows gradually in a ventral direction to reach the somato-splanchnopleuric angle, under cover of the growing myotome. It spreads out at its distal end and eventually separates into two portions: a smaller, splanchnic, or visceral; and a larger, somatic, or parietal portion. (1) The smaller, **splanchnic**, or **visceral portion** grows inwards, dorsal to the Wolffian ridge, to be connected with the sympathetic cord and the innervation of organs in the splanchnic area. This branch of the spinal nerve becomes the **white ramus communicans** of the sympathetic. It is not present in the case of all the spinal nerves (cervical, lower lumbar, and upper sacral). It will be referred to again in connection with the sympathetic system. (2) The larger, **somatic**, or **parietal portion** becomes the main part of the anterior primary division of the nerve. It continues the original ventral course of the nerve, and, reaching the body wall, subdivides into two terminal branches—a lateral branch, which grows outwards and downwards and reaches the lateral aspect of the trunk, after piercing the myotome; and a ventral or anterior branch, which grows onwards in the body wall to reach the ventral axis. This arrangement is met with in the trunk between the limbs and in the neck.

III. **Formation of Limb-plexuses.**—The method of growth of the spinal nerves, just described, is modified in the regions where the limbs are developed. In relation to the limbs, which exist in the form of buds of cellular undifferentiated mesoblast before the spinal nerves have any connection with them, the development of the nerve proceeds exactly in the way described up to the point of formation of somatic and splanchnic branches. The **somatic branches** then stream out into the limb bud, passing into it below the ends of the myotomes and spreading out into a bundle of fibres at the basal attachment of the limb. Later on, the nerves separate each into a pair of definite trunks, which are named **dorsal** and **ventral**, and which, dividing round a central core of mesoblast, proceed to the dorsal and ventral surfaces respectively of the limb bud. While this process is going on, a *secondary union* takes place between (parts of) adjacent dorsal and ventral trunks. Dorsal trunks unite with dorsal trunks, ventral trunks unite with ventral trunks, to form the nerves distributed ultimately to the surfaces and periphery of the limb. These **dorsal and ventral trunks** are homologous with the **lateral and ventral branches** of the somatic nerves in other regions.

Morphology of the Limb-plexuses.

The arrangement of the limb nerves is rendered complex and the significance of the plexuses is obscured by the changes through which, coincidently, the nerves on the one hand and the parts supplied by them on the other hand have passed in the course of development.

Nature of the Limbs.—As already described, the mammalian limbs arise as flattened buds from the extremities of the **Wolffian ridge**. Each bud possesses a *preaxial* and a *postaxial border*, and a *dorsal* and a *ventral surface*, continuous with the dorsal and ventral aspects of the trunk and homologous with its lateral and ventral surfaces. Each bud consists at first of a mass of undifferentiated, unsegmented mesoblast, covered by epithelium. Around the central core of mesoblast which produces the skeletal axis, the vessels and muscles of the limb are formed *in situ*, the muscles as double dorsal and ventral strata, beneath the corresponding surfaces of the bud.

Each limb bud is connected to the lateral and ventral aspects of the trunk, and is associated with a number of body segments, varying in the two extremities and in different animals.

Although the mesoblastic material of which the limb bud is composed exhibits in itself no segmental divisions at any period of its development, a clear indication of the segmental relations of the limbs is obtained from the arrangement of the limb nerves. Taking the nerves which supply the limbs as a guide, the segments engaged in the formation of the upper extremity are the last five cervical and first two thoracic. The lower extremity is related by its nerves to all the lumbar and the first three sacral segments. In each limb, the segments at the preaxial and postaxial borders are only partially concerned in limb formation.

It has been already shown that the somatic branches of the nerves enter the substance of the embryonic limb and divide in their course into dorsal and ventral trunks, which supply the dorsal and ventral surfaces of the limb bud. The higher nerves supply the preaxial border, the lower nerves supply the postaxial border, while the nerves most centrally situated extend furthest towards the periphery of the limb.

In order to understand properly the constitution of the limb-plexuses, it is necessary further to make a comparison of the surfaces and borders of the embryonic and adult limbs.

Upper Limb.—(*A*) **Borders.**—The **preaxial border** of the upper extremity extends from the middle of the clavicle, in the line of the cephalic vein, down the front of the shoulder, the outer side of the arm, forearm and hand, to the outer border of the thumb. The **postaxial border** extends from the middle of the axilla along the inner side of the arm (in the line of the basilic vein), the inner side of the forearm and hand, to the inner border of the little finger.

(*B*) **Surfaces.**—The areas of the limb between these lines, anteriorly and posteriorly, correspond to the ventral and dorsal surfaces of the embryonic limb bud. The **ventral surface** is represented by the front of the chest, arm and forearm, and the palm of the hand. The **dorsal surface** is represented by the scapular and deltoid regions, the back of the arm, forearm, and hand.

Lower Limb.—(*A*) **Borders.**—The **preaxial border** of the lower limb extends from the middle of Poupart's ligament down the inner side of the thigh and leg in the line of the internal saphenous vein, to the inner side of the great toe. The **postaxial border**, beginning at the coccyx, extends along the fold of the nates and the outer side and back of the thigh and leg (in the line of the external saphenous vein) to the outer border of the foot and little toe.

(*B*) **Surfaces.**—The areas between these lines correspond to the primitive dorsal and ventral surfaces of the embryonic limb bud. The unequal amount of rotation in the parts of the lower limb obscures the relation of fœtal and adult surfaces, which are most easily made out in the infantile position of the limbs, with the thighs and knees flexed and the soles of the feet inverted. The **ventral surface** of the embryonic limb is represented by the inner side and back of the thigh, the back of the leg, and the sole of the foot. The **dorsal surface** is represented by the front of the thigh and buttock, the front of the leg, and the dorsum of the foot.

Composition of the Limb-plexuses.—In all mammals the same definite plan underlies the constitution of the limb-plexuses. The nerves concerned are the anterior primary divisions of certain segmental spinal nerves, which (with certain exceptions at the preaxial and postaxial borders) are destined wholly and solely for the innervation of the limb. Each of the anterior primary divisions engaged divides into a pair of **secondary trunks**, named **dorsal** or posterior, **ventral** or anterior. The dorsal and ventral trunks again subdivide into **tertiary trunks**, which combine with the corresponding subdivisions of neighbouring dorsal and ventral trunks to form the **nerves of distribution**. The combinations of *dorsal trunks* provide a series of nerves for the supply of that part of the limb which is derived from the *dorsal surface* of the embryonic limb bud; the combinations of *ventral trunks* give rise to nerves of distribution to the regions corresponding to its *ventral surface.* The relation of the nerves derived from the limb-plexuses to the areas of the limbs is given in the accompanying tables :—

I. Upper Limb.

Origin.		Nerves.	Distribution.	
Brachial Plexus	**Dorsal trunks** (*Posterior cord*)	Posterior scapular Posterior thoracic Suprascapular Subscapular (3) Circumflex	Scapular region and shoulder	**Dorsal surface**
		(Lesser internal cutaneous (?)) (Intercosto-humeral (?))	Arm, inner side	
		Musculo-spiral	Back of arm, fore-arm, and hand	
	Ventral trunks (*Outer and inner cords*)	Nerve to subclavius Anterior thoracic (2)	Front of chest	**Ventral surface**
		Musculo-cutaneous	Front of arm and forearm	
		Lesser internal cutaneous	Inner side of arm	
		Internal cutaneous	Front of arm and forearm	
		Median Ulnar	Front of forearm and hand	

II. Lower Limb.

Origin.		Nerves.	Distribution.	
Lumbo-sacral Plexus	Dorsal trunks	Ilio-hypogastric (iliac branch) Superior gluteal Inferior gluteal Nerve to pyriformis Small sciatic . . .	Buttock	Dorsal surface
		External cutaneous . . .	Buttock and thigh, outer side and front	
		Genito-crural (crural branch)	Front of thigh	
		Anterior crural . . .	Front and inner side of thigh, leg, and foot	
		Peroneal	Front of leg and foot	
	Ventral trunks	Ilio-hypogastric (hypogastric branch)	Abdominal wall (ventral surface)	Ventral surface
		Ilio-inguinal . . .	Abdominal wall, thigh, and perineum	
		Genito-crural (genital branch)	Groin	
		Obturator	Thigh (inner side) and knee (back)	
		Nerve to obturator internus and superior gemellus Nerve to quadratus femoris and inferior gemellus Nerve to hamstrings	Buttock and back of thigh	
		Small sciatic . . .	Back of thigh and perineum	
		Tibial	Back of knee, leg, and sole of foot	

In the regions of the limbs no anterior cutaneous branches, derived from the limb nerves, supply the trunk. The whole of the nerve is carried into the limb and is absorbed in its innervation, and the dorsal and ventral trunks forming the limb-plexuses are to be looked upon as homologous with the lateral and anterior trunks of an intercostal nerve. Two series of anomalies in relation to the formation and distribution of the nerves to the limbs must, however, be considered, because it has been suggested (Goodsir) that the nerves of the limbs are serially homologous with not the whole, but with only the lateral branches of the anterior primary divisions of the intercostal nerves.

(1) **Nerves in connexion with the primitive borders of the Limbs.—At the preaxial border of the upper limb,** at its root, the fourth cervical nerve, which supplies the anterior and lateral surfaces of the neck, is also distributed through the supraclavicular nerves to the skin of both ventral and dorsal surfaces of the limb. The nerves and surfaces are here not merely homologous, but in actual continuity.

At the preaxial border of the lower limb, similarly, the first lumbar nerve, by means of the ilio-hypogastric and ilio-inguinal branches, supplies on the one hand the buttock, in series with the lateral branches of the lower thoracic nerves, and, on the other hand, the lower part of the abdominal wall and the adjacent inner side of the thigh, in series with the anterior terminal branches of the lower thoracic nerves.

At the postaxial border of the upper limb the first and second thoracic nerves are concerned in supplying trunk segments as well as parts of the limb. The first thoracic nerve, besides supplying the limb through the inner cord of the plexus, also innervates at least the muscles of the first intercostal space ; the second thoracic nerve is concerned in the innervation of the limb, principally by means of its lateral branch only, which, as the intercosto-humeral nerve, supplies the skin along the postaxial border of the limb and on its *dorsal side.* **At the postaxial border of the lower limb,** in the same way, the third and fourth sacral nerves, partially implicated in the innervation of the limb (through the tibial, small sciatic, perforating cutaneous nerve, and perineal branch of the fourth sacral nerve), are also engaged in supplying the trunk (perineum) through the pudic nerve. These peculiarities of arrangement of the nerves at the borders of the limbs may be explained on the supposition that the segment corresponding to the nerve named is only partially concerned in limb formation, and is, at the same time, implicated to a greater or less extent in the formation of structures belonging to the trunk.

(2) **The origin and distribution of the nerves at the postaxial border of the limbs** present a special difficulty. In the composition respectively of the brachial and lumbo-sacral plexuses, the first thoracic and third sacral nerves do not as a rule divide into ventral and dorsal trunks, but contribute only to the formation of the ventral series of nerves. A solution of this difficulty may be found in the examination of the areas of distribution of the nerves derived from the first thoracic and third sacral nerves. In the case of the brachial plexus (the inner cord of which

receives normally the whole contribution of the first thoracic nerve) the lesser internal cutaneous, the inner branch of the internal cutaneous, and the dorsal branch of the ulnar nerve supply the dorsal aspect of the limb on its postaxial border. These nerves are in serial homology with the intercosto-humeral and lateral trunks of intercostal nerves. In the case of the lumbo-sacral plexus similarly, in which the third sacral nerve does not divide into ventral and dorsal trunks, the small sciatic and tibial nerves containing the contribution from the third sacral nerves innervate, by means of the gluteal and external femoral branches of the former and the tibial communicating branch of the latter, the dorsal surface of the limb along the postaxial border, in series with the perforating cutaneous nerve and the perineal branch of the fourth sacral.

These apparent anomalies appear to indicate that, instead of dividing into its proper dorsal and ventral trunks, the entire contribution of the spinal nerve concerned is in these instances carried undivided along the postaxial border of the limb in association with the ventral trunks, and that the dorsal subdivisions are thrown off successively as the plexus cords approach the periphery. Indeed, in the case of the small sciatic nerve, Eisler has shown that, when the peroneal and tibial nerves are separated at their origin, its gluteal and external femoral branches arise from and are connected with the former, and the perineal and internal femoral branches with the latter trunk.

The Distribution of the Spinal Nerves to the Muscles and Skin of the Limbs.

By dissection, experiment, and clinical observation, it is conclusively proved that as a rule each nerve of distribution in the limb, whether to muscle or skin, is made up of fibres derived from more than one spinal nerve; and, further, that in cutaneous distribution a considerable overlapping occurs in the course of the several peripheral nerves. Moreover, the arrangement of the distribution of the nerves to skin and to muscles is not identical. In the case of the skin of the limbs, by the covering of the limb being drawn on to it from adjacent parts in the process of growth, cutaneous nerves are engaged, which are derived from sources not represented in the muscular innervation of the limbs. Again, among the muscles, some have undergone fusion, others have become rudimentary, and others again have altered their position in the limb. Bearing these qualifications in mind, it is possible to formulate a definite plan for the innervation of the skin and muscles of the upper and lower limb. The accompanying tables give an analysis of the distribution of the spinal nerves to the skin and muscles of the upper and lower limb respectively:—

I. Upper Limb.

A. Cutaneous Nerves.

1. Dorsal (Posterior) Surface.

Regions.		Nerves.	Spinal Origins. Preaxial Nerves.	Spinal Origins. Postaxial Nerves.
Scapular	Upper part (*preaxial*)	Posterior primary division, cervical	C. 4. 5. 6.	
		Cervical plexus, acromial	C. 3. 4.	
	Lower part (*postaxial*)	Posterior primary divisions, thoracic	T. 1.-7.	
		Intercostal nerves, lateral branches	T. 2. 3. 4.	
Deltoid	Upper part (*preaxial*)	Cervical plexus, acromial	C. 3. 4.	
		Circumflex	C. 5. 6.	
	Lower part (*postaxial*)	Intercostal nerves, lateral branches		T. 2. 3.
Upper arm	Outer side (*preaxial*)	Circumflex	C. 5. 6.	
		Musculo-spiral, upper external branch	C. (5). 6.	
	Inner side (*postaxial*)	Musculo-spiral, internal branch		C. 8.
		Lesser internal cutaneous		T. 1.
		Intercosto-humeral		T. 2.

1. Dorsal (Posterior) Surface—*continued.*

Regions.		Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Forearm	Outer side (*preaxial*)	Musculo-spiral, upper external branch	C. (5). 6.	
		Musculo-spiral, lower external branch	C. 6. 7. 8.	
		Musculo-cutaneous, posterior branch	C. 5. 6.	
		Radial	C. 6. 7.	
	Inner side (*postaxial*)	Internal cutaneous, internal branch		C. 8. T. 1.
		Ulnar, dorsal branch		C. 8.
Hand	Outer side (*preaxial*)	Radial	C. 6. 7.	
	Inner side (*postaxial*)	Ulnar		C. 8.

I. Upper Limb.

A. Cutaneous Nerves

2. Ventral (Anterior) Surface.

Regions.		Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Chest	Upper part (*preaxial*)	Cervical plexus, supraclavicular branches	C. 3. 4.	
	Lower part (*postaxial*)	Intercostal nerves, anterior branches; Intercostal nerves, lateral branches		T. 2-7.
Upper arm	Outer part (*preaxial*)	Circumflex	C. 5. 6.	
		Musculo-spiral, upper external branch	C. 5. 6.	
	Inner part (*postaxial*)	Internal cutaneous		C. 8. T. 1.
		Lesser internal cutaneous		T. 1.
		Intercosto-humeral		T. 2.
Forearm	Outer part (*preaxial*)	Musculo-cutaneous, anterior branch	C. 5. 6.	
	Inner part (*postaxial*)	Internal cutaneous, anterior branch		C. 8. T. 1.
Hand	Outer part (*preaxial*)	Musculo-cutaneous, ball of thumb	C. 5. 6.	
		Median, palmar branch	C. 6. 7.	
		,, digital branches	C. 6. 7. 8. T. 1.	
		,, thumb, outer side	C. 6. (7).	
		,, ,, inner side; ,, index, outer side	C. 6. 7.	
		,, ,, inner side; ,, middle, outer side	C (6). 7. 8. (T. 1).	
		,, ,, inner side; ,, ring, outer side		C. 8. T. 1.
	Inner part (*postaxial*)	Ulnar, palmar branch		T. 1.
		,, digital branches		T. 1.

I. Upper Limb.

B. Muscular Nerves.

1. Dorsal (Posterior) Surface.

Regions.		Muscles.	Nerves	Spinal Origins. *Preaxial Nerves. Postaxial Nerves.*
Shoulder	Upper part (*preaxial muscles*)	Trapezius	Cervical plexus .	C. 3. 4.
		Levator anguli scapulæ .	Cervical plexus . / Posterior scapular	C. 3. 4. / C. 5.
		Rhomboidei	Posterior scapular	C. 5.
		Serratus magnus . . .	Posterior thoracic	C. 5. 6. 7.
		Supraspinatus / Infraspinatus . . .	Suprascapular .	C. 5. 6.
		Subscapularis . . .	Short subscapular / Middle ,,	C. 5. 6.
	Lower part (*postaxial muscles*)	Teres major	Middle subscapular	C. 5. 6.
		Teres minor / Deltoid . . .	Circumflex . .	
		Latissimus dorsi . . .	Long subscapular	C. 6. 7. 8.
Upper arm . .		Triceps	Musculo-spiral	
		Outer head . . .	Musculo-spiral	C. (6). 7. 8.
		Middle head . . .	Musculo-spiral	
		Inner head . . .	Musculo-spiral	C. 7. 8.
		Anconeus	Musculo-spiral	
Forearm . . .		Brachio-radialis . . .	Musculo-spiral	C. 5. 6
		Extensor carpi radialis longior	Musculo-spiral	C. (5). 6. 7. (8).
		Extensor carpi radialis brevior	Posterior inter-osseous . .	C. (5). 6. 7. (8).
		Supinator radii brevis . .	Posterior inter-osseous . .	C. (5) 6.
		Extensor communis digitorum	Posterior inter-osseous . .	C. (5). 6. 7. 8.
		,, minimi digiti . .	Posterior inter-osseous . .	C. (5). 6. 7. 8.
		,, carpi ulnaris . .	Posterior inter-osseous . .	C. (5). 6. 7. 8.
		Extensor ossis metacarpi pollicis	Posterior inter-osseous . .	C. (5). 6. 7. 8.
		Extensor longus pollicis .	Posterior inter-osseous . .	C. (5). 6. 7. 8.
		,, brevis pollicis .	Posterior inter-osseous . .	C. (5). 6. 7. 8.
		,, indicis . . .	Posterior inter-osseous . .	C. (5). 6. 7. 8.

I. Upper Limb.

B. Muscular Nerves.

2. Ventral (Anterior) Surface.

Regions.		Muscles.	Nerves.	Spinal Origins. *Preaxial Nerves. Postaxial Nerves.*
Pectoral Region	Upper part (*preaxial muscles*)	Sternomastoid . . .	Cervical plexus .	C. 2.
		Omohyoid / Sternohyoid . . .	Ansa hypoglossi .	C. 1. 2. 3.
		Subclavius	Brachial plexus .	C. 5. 6.
	Lower part (*postaxial muscles*)	Pectoralis major . . .	Anterior thoracic nerves . .	C. 5. 6. 7. 8. T. 1.
		Clavicular part . .	Anterior thoracic nerves . .	C. 5. 6.
		Sternal part . . .	Anterior thoracic nerves . .	C. 5. 6. 7. 8. T. 1.
		Pectoralis minor . . .	Anterior thoracic nerves . .	C. 7. 8. T. 1.

2. **Ventral (Anterior) Surface**—*continued.*

Regions.		Muscles.	Nerves.	Spinal Origins. Preaxial Nerves.	Spinal Origins. Postaxial Nerves.
Upper arm	Outer part (*preaxial*)	Biceps	Musculo-cutaneous	C. 5. 6.	
		Brachialis anticus . .	Musculo-cutaneous; Musculo-spiral	C. (5). 6.	
		Coraco-brachialis . . .	Musculo-cutaneous	C. 7.	
	Inner part (*postaxial*)	Axillary arches	Internal anterior thoracic, or lesser internal cutaneous, or intercosto-humeral		C. 8. T. 1. (2).
Forearm	Outer part (*preaxial*)	Pronator radii teres . .	Median	C. 6.	
		Flexor carpi radialis . .	Median	C. 6.	
		Palmaris longus . . .	Median		
		Flexor sublimis digitorum .	Median		
	Inner part (*postaxial*)	Flexor profundus digitorum	Anterior interosseous: Ulnar	C. 7. 8. T. 1.	C. 8. T. 1.
		Flexor carpi ulnaris . .	Ulnar . . .		C. 8. T. 1.
		Flexor longus pollicis . .	Anterior interosseous . .	C. 7. 8. T. 1.	
		Pronator quadratus . .	Anterior interosseous . .	C. 7. 8. T. 1.	
Hand	Outer part (*preaxial*)	Abductor pollicis . . .	Median . .	C. 6. 7.	
		Opponens pollicis . .	Median . .	C. 6. 7.	
		Flexor brevis pollicis . .	Median . .	C. 6. 7.	
		Two outer lumbricales . .	Median . .	C. 6. 7.	
	Inner part (*postaxial*)	Two inner lumbricales . .	Ulnar . . .	C. 8. (T. 1).	
		Interossei	Ulnar . . .	C. 8. (T. 1).	
		Adductores pollicis (transversus et obliquus) .	Ulnar . . .	C. 8. (T. 1).	
		Abductor minimi digiti .	Ulnar . . .	C. 8. (T. 1).	
		Opponens minimi digiti .	Ulnar . . .	C. 8. (T. 1).	
		Flexor brevis minimi digiti	Ulnar . . .	C. 8. (T. 1).	

II. Lower Limb.

A. Cutaneous Nerves.

1. Dorsal Surface.

(*Front and outer side of thigh, buttock, front of leg, dorsum of foot.*)

Regions.		Nerves.	Spinal Origins. Preaxial Nerves.	Spinal Origins. Postaxial Nerves.
Front of thigh and front part of buttock (*preaxial nerves*)	Thigh	Genito-crural, crural branch .	L. 1. 2.	
		Anterior crural, internal branch .	L. 2. 3.	
		Anterior crural, middle branch .	L. 2. 3.	
		External cutaneous	L. 2. 3.	
	Buttock	Twelfth thoracic, iliac branch .	T. 12.	
		Ilio-hypogastric, iliac branch .	L. 1.	
		Posterior primary divisions, lumbar	L. 1. 2. 3.	
Outer side of thigh and buttock, back and lower part (*postaxial nerves*)		Posterior primary divisions, sacral		S. 1-5.
		Posterior primary divisions, coccygeal		Co.
		Small sciatic: gluteal, and femoral branches		S. 1. 2. 3.
Leg . .	Inner side (*preaxial*)	Internal saphenous; Patellar branch . . .	L. 3. 4.	
	Outer side (*postaxial*)	Musculo-cutaneous . . .	L. 4. 5. S. 1.	
		Peroneal, sural branches . .	L. (4). 5. S. 1.	
Dorsum of foot	Inner side (*preaxial*)	Internal saphenous . . .	L. 3. 4.	
		Anterior tibial	L. 4. 5. (S. 1).	
	Outer side (*postaxial*)	Musculo-cutaneous . . .	L. 4. 5. S. 1.	
		External saphenous . . .		S. 1. (2).

II. **Lower Limb.**

A. **Cutaneous Nerves.**

2. **Ventral Surface.**

(*Inner side and back of thigh, back of leg, and sole of foot.*)

Regions.		**Nerves.**	**Spinal Origins.** *Preaxial Nerves.*	*Postaxial Nerves.*
Inner side and back of thigh	Inner side of thigh (*preaxial*)	Ilio-inguinal	L. 1.	
		Obturator	L. 2. 3. (4).	
	Back of thigh (*postaxial*)	Small sciatic, femoral branches		S. 1. 2. 3.
Back of leg		Peroneal, sural branches	L. (4). 5. S. 1.	
		Peroneal, communicans fibularis		
		Small sciatic		S. 1. 2. 3.
		External saphenous		S. 1. (2).
Sole of foot	Inner side (*preaxial*)	Internal saphenous	L. 3. 4.	
		Posterior tibial, calcanean		S. 1. 2.
		Internal plantar	L. 4. 5. S. 1.	
		Great toe, inner side	L. 4. 5.	
		,, ,, outer side	L. 4. 5. S. 1.	
		Second toe, inner side		
		,, ,, outer side	L. 5. S. 1.	
		Third toe, inner side		
		,, ,, outer side		
		Fourth toe, inner side		
	Outer side (*postaxial*)	External plantar	S. 1. 2.	
		Fourth toe, outer side		
		Fifth toe, inner side		
		,, ,, outer side		
		External saphenous	S. 1. (2).	

II. **Lower Limb.**

B. **Muscular Nerves.**

1. **Dorsal Surface.**

(*Front and outer side of thigh, buttock, front and outer side of leg, dorsum of foot.*)

Regions.	**Muscles.**	**Nerves.**	**Spinal Origins.** *Preaxial Nerves.*	*Postaxial Nerves.*
Front of thigh (*preaxial*)	Pectineus	Anterior crural	L. 2. 3.	
	Sartorius			
	Iliacus		L. 2. 3. 4.	
	Psoas			
	Quadriceps extensor		L. 3. 4.	
	Vastus internus			
	Rectus femoris			
	Crureus			
	Vastus externus			
Buttock and outer side of thigh (*postaxial*)	Tensor fasciæ femoris	Superior gluteal		L. 4. 5. S. 1.
	Gluteus minimus			
	,, medius			
	,, maximus	Inferior gluteal		L. 5. S. 1. 2.
	Biceps, short head	Peroneal		
	Pyriformis	Sacral plexus		S. 1. 2.

1. Dorsal Surface—*continued.*

Regions.		Muscles.	Nerves.	Spinal Origins. *Preaxial Nerves.*
Front of leg	Inner side (*preaxial*)	Tibialis anticus	Anterior tibial	L. 4. 5. S. 1.
		Extensor proprius hallucis		
		Extensor longus digitorum		
		Peroneus tertius		
	Outer side (*postaxial*)	Peroneus longus	Musculo-cutaneous	
		Peroneus brevis		
Dorsum of foot		Extensor brevis digitorum	Anterior tibial	

II. Lower Limb.

B. Muscular Nerves.

2. Ventral Surface.

(*Inner side and back of thigh, back of leg, and sole of foot.*)

Regions.		Muscles.	Nerves.	Spinal Origins. *Preaxial Nerves.* *Postaxial Nerves.*
Thigh and buttock	Thigh, inner side (*preaxial*)	Adductor longus	Obturator	L. 2. 3.
		Gracilis		L. 2. 3. 4.
		Adductor brevis		
		Obturator externus		L. 3. 4.
		Adductor magnus		
	Thigh, outer side (*postaxial*)	Adductor magnus	Nerve to hamstrings	L. 4. 5. S. 1.
		Semimembranosus		L. 5. S. 1. 2.
		Semitendinosus		S. 1. 2. 3.
		Biceps, long head		
	Buttock	Quadratus femoris and superior gemellus	Sacral plexus	L. 4. 5. S. 1.
		Inferior gemellus and obturator internus		S. 1. 2. 3.
Back of leg		Plantaris	Tibial	L. 4. 5. S. 1.
		Popliteus		
		Flexor longus digitorum	Posterior tibial	L. 5. S. 1.
		Tibialis posticus		
		Flexor longus hallucis		L 5. S. 1. 2.
		Soleus		
		Soleus	Tibial	S. 1. 2.
		Gastrocnemius (each head)		
Sole of foot	Inner side (*preaxial*)	Abductor hallucis	Internal plantar	L. 4. 5. S. 1.
		Flexor brevis digitorum		
		Flexor brevis hallucis		
		First lumbricalis		
	Outer side (*postaxial*)	Second, third, and fourth lumbricales	External plantar	S. 1. 2.
		Flexor accessorius		
		Adductores hallucis		
		Interossei		
		Flexor brevis minimi digiti		
		Abductor minimi digiti		

A. Innervation of the Muscles of the Limbs.—The following laws appear to be applicable to the upper and lower limbs alike :—

1. *No limb-muscle receives its nerve-supply from posterior primary divisions.*

2. *The dorsal and ventral strata of muscles are always supplied by the corresponding dorsal and ventral branches of the nerves concerned. The ventral muscular stratum is more extensive than the dorsal; the ventral nerves are the more numerous, and the additional nerves are postaxially placed.* The spinal nerves supplying muscles of the upper limb are C. 5, 6, 7, 8 (dorsal), and C. 5, 6, 7, 8, T. 1 (ventral); the nerves for the muscles of the lower limb are L. 2, 3, 4, 5, S. 1, 2 (dorsal), and L. 2, 3, 4, 5, S. 1, 2, 3 (ventral).

3. *The dorsal and ventral trunks of the nerves are distributed in the limb in a continuous, segmental manner;* so that, "of two muscles, that nearer the head end of the body tends to be supplied by the higher nerve, and that nearer the tail end by the lower nerve" (Herringham).

4. *The nerves placed most centrally in the plexus extend furthest into the limb, and the more preaxial nerves terminate sooner in the limb than the more postaxial nerves.*

Upper Limb.

Dorsal Surface.		Ventral Surface.	
Muscles of shoulder	C. 3, 4, 5, 6, 7, 8.	Muscles of chest	C. 5, 6, 7, 8, T. 1.
„ arm	C. 6, 7, 8.	„ arm	C. 5, 6, 7.
„ forearm	C. 6, 7.	„ forearm	C. 6, 7, 8, T. 1.
		„ hand	C. 6, 7, 8 (T. 1).

Lower Limb.

Muscles of thigh and buttock	L. 2, 3, 4, 5, S. 1, 2.	Muscles of thigh	L. 2, 3, 4, 5, S. 1, 2, 3.
Muscles of leg and foot	L. 4, 5, S. 1.	„ leg	L. 4, 5, S. 1, 2.
		„ foot	L. 5, S. 1, 2.

The only exception to this rule is on the ventral (anterior) surface of the upper arm, where a suppression of the muscle elements leads to an absence of the regular series of segmental nerves (C. 8, T. 1) on its postaxial border. These nerves reappear in the forearm, and the occasional

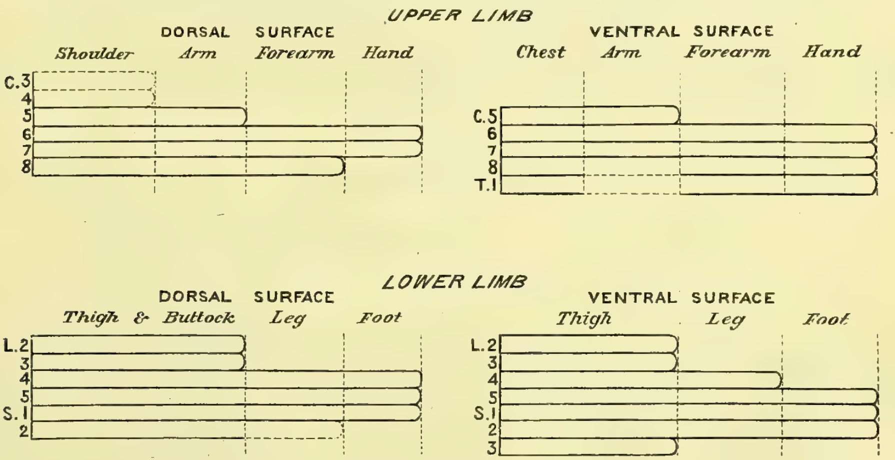


FIG. 451.—SCHEME of the segmental distribution of the muscular nerves of the upper and lower limbs.

"axillary arches" may be regarded as the muscular elements usually suppressed, and, when present, supplied by these nerves.

Muscles with a Double Nerve-supply.—The existence of more than one nerve to a muscle indicates usually that the muscle is composite and is the representative of originally separate elements, belonging to one or both surfaces of the limb. In the case of the pectoralis major, subscapularis and flexor profundus digitorum, adductor magnus, and soleus, parts of the same (ventral or dorsal) stratum have fused, to form muscles innervated from their corresponding ventral or dorsal nerves. The other muscles having a double nerve-supply—brachialis anticus, biceps flexor cruris, and (sometimes) pectineus—are examples of fusion at the preaxial or postaxial border of muscular elements derived from the dorsal and ventral surfaces of the limb, which are correspondingly innervated by branches from both dorsal and ventral series: *e.g.* the brachialis anticus is innervated by the musculo-cutaneous and musculo-spiral nerves; the biceps flexor cruris, by the peroneal (short head) and tibial (long head) nerves; and the pectineus, by the anterior crural and (sometimes) obturator nerves.

B. Innervation of the Skin of the Limbs.—While the scheme of cutaneous innervation of the limbs is fundamentally segmental, yet the arrangement is confused and complicated by various causes. The growth of the limb from the trunk has caused the skin to be drawn out over it like a stretched sheet of india-rubber (Herringham), and at the same time the extent of the dorsal area of the limb is increased at the expense of the ventral area. The central nerves of the plexus remain buried deeply in the substance of the limb, only coming to the surface towards the periphery. The proximal parts of both surfaces of the limb thus become innervated by

cutaneous nerves otherwise not necessarily concerned in the innervation of the limbs. Herringham has shown that—(A) *Of two spots on the skin, that nearer the preaxial border tends to be supplied by the higher nerve.* (B) *Of two spots in the preaxial area, the lower tends to be supplied by the lower nerve; and, of two spots in the postaxial area, the lower tends to be supplied by the higher nerve.* In other words, from the root of the limb down the preaxial border to its distal extremity, and up the postaxial border to the root of the limb again, there is a definite numerical sequence of spinal nerves supplying skin areas through nerves of the limb-plexuses. A similar numerical sequence in the arrangement of the nerves is also found extending over the dorsal and ventral surfaces of the limbs from preaxial to postaxial border, except in certain situations.

On the dorsal and ventral surfaces of both upper and lower limbs there is a hiatus, for a certain distance, in the numerical sequence of the spinal nerves in their cutaneous distribution, explicable on the ground that the central nerves of the plexus, which fail to reach the surface in these situations, are replaced by cutaneous branches from neighbouring nerves. This hiatus has been named the *axial area or line.*

In the upper limb, *the dorsal axial area or line* extends from the middle line of the back, opposite the vertebra prominens, to the insertion of the deltoid.

The ventral axial area or line extends anteriorly from the middle line of the trunk, at the manubrio-sternal joint, across the chest, down the front of the arm and forearm to the wrist.

In the lower limb, *the dorsal axial area or line* may be traced from the middle line of the back over the posterior superior iliac spine, across the buttock and thigh, to the head of the fibula.

A ventral axial area or line can also be traced from the root of the penis along the inner side of the thigh and knee, and down the back of the leg to the heel.

These areas or lines represent the meeting-place and overlapping of nerves, which are not in numerical sequence; and it is only at the peripheral parts of the limbs, on the dorsal and ventral surfaces, that the nerves appear in numerical sequence from the preaxial to the postaxial border. In the case of the upper limb the hiatus is caused, in both surfaces of the limb, by the absence of cutaneous branches of the seventh cervical nerve; in the case of the lower limb the hiatus is due to the absence of branches from the fifth lumbar nerve on both surfaces of the limb, and the absence of branches from the fourth lumbar nerve, in addition, on the dorsal surface.

Understanding the significance of these dorsal and ventral axial areas or lines, and at the same time bearing in mind the overlapping which occurs in the cutaneous distribution of each spinal nerve, the areas of skin supplied through the limb-plexuses can be mapped out with considerable precision, as indicated in the following tables:—

A. Upper Limb.

Cutaneous Distribution.

Nerves.		Spinal Origin.	Distribution.
Preaxial border from neck to hand ↓	Supraclavicular nerves	C. 3. 4.	Chest, shoulder, deltoid, and scapular regions.
	Circumflex . . .	C. 5. 6.	Deltoid region, outer side of arm.
	Musculo-spiral (upper external)	C. (5). 6.	Outer side and back of arm and forearm.
	Musculo-spiral (lower external)	C. 6. 7. 8.	Outer side and back of elbow and forearm.
	Musculo-cutaneous .	C. 5. 6.	Outer side of forearm, in front and behind.
Hand — Dorsum	Radial . . .	C. 6. 7.	Outer side
	Ulnar	C. 8.	Inner side } of dorsum of hand.
Hand — Palm	Musculo-cutaneous .	C. 5. 6.	Ball of thumb.
	Median . . .	C. 6. 7.	Outer side
	Ulnar	T. 1.	Inner side } of palm of hand.
Digits . .	Median . . .	C. 6. 7. 8. T. 1.	Thumb, C. 6. 7. First finger, C. 6. 7. 8. Second „ C. 7. 8. T. 1. Third „ C. 8. T. 1. Fourth „ Fifth „ } T. 1.
	Ulnar . . .	C. 8. T. 1.	
Postaxial border from hand to chest ↑	Internal cutaneous .	C. 8. T. 1.	Inner side of forearm, in front and behind.
	Musculo-spiral (internal)	C. 8.	Inner side of arm.
	Lesser internal cutaneous	T. 1.	
	Intercosto-humeral .	T. 2.	
	Intercosto-humeral .	T. 2.	Axillary folds.
	Third intercostal .	T. 3.	
	Fourth „ . .	T. 4.	

B. Lower Limb.

Cutaneous Distribution.

	Nerves.	Spinal Origin.	Distribution.
Preaxial border from trunk to foot ↓	Iliac branch of twelfth thoracic	T. 12.	Outer side of buttock.
	Iliac branch of ilio-hypogastric	L. 1.	Outer side of buttock.
	Ilio-inguinal . .	L. 1.	Groin and over Scarpa's triangle.
	Genito-crural . .	L. 1. 2.	Front of thigh, upper third.
	External cutaneous .	L. 2. 3.	Front and outer side of thigh.
	Anterior crural (middle and internal)	L. 2. 3.	Front and inner side of thigh, lower two-thirds.
	Obturator . . .	L. 2. 3. (4).	Inner side of thigh, middle third.
	Anterior crural (internal saphenous)	L. 3. 4.	Knee and leg, inner side and front.
Foot — Dorsum	Internal saphenous .	L. 3. 4.	Inner side of foot.
	Anterior tibial . .	L. 4. 5. S. (1).	Interval between first and second toes.
	Musculo-cutaneous .	L. 4. 5. S. 1.	Dorsum of foot and toes.
	External saphenous .	S. 1. (2).	Outer side of foot.
Foot — Sole	Internal plantar .	L. 4. 5. S. 1.	Inner part of sole.
	External plantar .	S. 1. 2.	Outer part of sole.
	Posterior tibial (calcanean)	S. 1. 2.	Heel and back part of sole.
Digits .	Internal and external plantar	L. 4. 5. S. 1. S. 1. 2.	Great toe, L. 4. 5. S. 1. Second toe, L. 4. 5. S. 1. Third ,, L. 5. S. 1. Fourth ,, L. 5. S. 1. 2. Fifth ,, S. 1. 2.
Postaxial border from foot to coccyx ↑	External saphenous .	S. 1. (2).	Outer side of foot and leg, lower third.
	Small sciatic . .	S. 1. 2. 3.	Back of leg, thigh, and buttock.
	Perforating cutaneous.	S. 2. 3.	Buttock (fold of nates, inner half).
	Sacro-coccygeal . .	S. 4. 5. Co. 1.	Anal fold.

Variations in the Position of the Limb-plexuses.

Two different kinds of variations occur in relation to the limb-nerves.

(1) **Individual variations,** in both the extent of origin and in the area of distribution of a given nerve, are not uncommon ; these variations are usually concomitant with compensatory variations in adjacent nerves, and are due to the fibres of a given spinal nerve taking an abnormal course in the trunk of another nerve of distribution and effecting a communication with the proper nerve peripherally. In this way the variations in the origin and distribution of the intercosto-humeral nerve may be explained ; and, similarly, the ulnar nerve may have some of its fibres carried as far as the forearm incorporated with the median and transferred to it by a communication between the two nerves in that region.

(2) **Variations in the limb-plexus,** in relation to the vertebral column, are the chief cause of variations in the constitution of the limb-nerves. These variations affect more or less the whole series of nerves in the plexus.

The **brachial plexus** is subject only to very slight variation in position and arrangement. It may be reinforced at the upper end by a slender trunk from the fourth cervical nerve, and, more frequently, by an intra-thoracic communication between the second and first thoracic nerves. The presence of one or other of these nerves is an indication of a slight tendency towards a cephalic or caudal shifting of the whole plexus in relation to the spinal cord. It is, however, never sufficient to cause the exclusion to any extent of the nerves normally implicated. The presence of a cervical rib may coincide with little or no change in the relation of the nerves. Indeed, the inclusion of the second thoracic nerve in the plexus may be, as already stated, merely an individual variation, a change in the path to the limb of the intercosto-humeral nerve. Concomitant variations occur among groups of nerves, however, which indicate a certain tendency to variation in the position of the whole plexus. At one end, the suprascapular and musculo-cutaneous nerves may arise from the fourth and fifth, fifth alone, or fifth and sixth cervical nerves. At the other end of the plexus, the musculo-spiral may or may not receive a root from the first thoracic nerve, and this addition is rather more likely to occur when the second thoracic nerve is implicated in the plexus.

The **lumbo-sacral plexus** shows a very considerable variability in position and constitution. Eisler records concomitant variations in the plexus in 18 per cent of the cases examined by him. The variations occur within wide limits. The plexus may begin at the eleventh or twelfth thoracic or first lumbar nerve. The last nerve in the great sciatic cord may be the second, third, or fourth sacral nerve. The position of the n. furcalis is a guide to the arrangement of the plexus. It may be formed by the third, third and fourth, fourth, fourth and fifth, or fifth lumbar nerves. The resulting variations are illustrated by the following extreme cases :—

	(1) *Prefixed Variety.*	(2) *Postfixed Variety.*
Nervus furcalis . . .	L. 3 and 4 (double)	L. 5.
Obturator . . .	L. 1, 2, 3.	L. 2, 3, 4, 5.
Anterior crural . . .	T. 12, L. 1, 2, 3, 4.	L. 2, 3, 4, 5.
Tibial	L. 3, 4, 5, S. 1, 2.	L. 5, S. 1, 2, 3, 4.
Peroneal	L. 3, 4, 5, S. 1.	L. 5, S. 1, 2, 3.

Those variations in the constitution of the lumbo-sacral plexus are most numerous which are due to the inclusion of nerves more caudally placed. Thus, out of twenty-two variations in the position of the *n. furcalis*, in nineteen Eisler found it formed by the fifth lumbar nerve; in two cases only, by the third lumbar nerve. There is further evidence that variations in the position of the plexus are accompanied by variations in the vertebral column itself. Out of the twenty-two abnormal plexuses examined by Eisler, sixteen were coincident with abnormal arrangement of the associated vertebræ.

Significance of the Limb-plexuses.

From the above considerations, it is obvious that something more than convenience of transit for the spinal nerves to skin and muscles is secured by the formation of the limb-plexuses. It has been shown that by their combinations in the plexuses, every spot or area of skin in the limbs is innervated by more than one spinal nerve; and generally, also, each limb-muscle is supplied by more than one spinal nerve. Each cutaneous area and each limb-muscle is thus brought into relationship with a wider area of the spinal cord than would occur if the plexuses were non-existent. A simultaneous record of sensation is thus transmitted from any given point on the surface of the limb through more than one dorsal root; and a more ready co-ordination of muscular movement is brought about by the transmission of motor impulses from the ventral root of a given spinal nerve to more than one muscle at the same time. In a word, a plexus exists to supply the whole limb and the limb as a whole, as an organ which has its different active parts connected with the central nervous system by means of the limb-plexus.

THE CRANIAL NERVES.

There are twelve pairs of cranial nerves. They present striking differences from one another—in origin, in distribution, and in functions, as will be seen in the following table :—

Number.	Name.	Function.	Superficial Attachment to Brain.
I.	**Olfactory** . .	Smell	Olfactory bulb.
II.	**Optic** . .	Sight	Optic thalamus.
III.	**Oculo-motor** .	Motor to the muscles of eyeball and orbit	Crus cerebri.
IV.	**Trochlear** . .	Motor to superior oblique muscle of eyeball	Superior medullary velum.
V.	**Trigeminal** .	Sensory to face, tongue, and teeth; motor to muscles of mastication	Pons Varolii.
VI.	**Abducent** . .	Motor to external rectus muscle of eyeball	Junction of pons and medulla.
VII.	**Facial** . .	Motor to muscles of scalp and face, sensory to tongue	Posterior border of pons Varolii.
VIII.	**Auditory** . .	Hearing and equilibrium . . .	Posterior border of pons Varolii.
IX.	**Glosso-pharyngeal**	Sensory to tongue and pharynx .	Medulla oblongata.
X.	**Pneumo-gastric**	Sensory to pharynx, œsophagus and stomach, and respiratory organs	Medulla oblongata.

THE CRANIAL NERVES—*continued.*

Number.	Name.	Function.	Superficial Attachment to Brain.
XI.	**Spinal accessory**	(*a*) **Accessory to vagus.** Motor to muscles of palate, pharynx, œsophagus, stomach and intestines, and respiratory organs ; inhibitory for heart.	Medulla oblongata.
		(*b*) **Spinal part**: motor to trapezius and sterno-mastoid muscles	Spinal cord.
XII.	**Hypoglossal** .	Motor to muscles of the tongue .	Medulla oblongata.

The deep cerebral connexions of the cranial nerves are dealt with in the section which treats of the Brain (pp. 476 and 499). Certain general points in

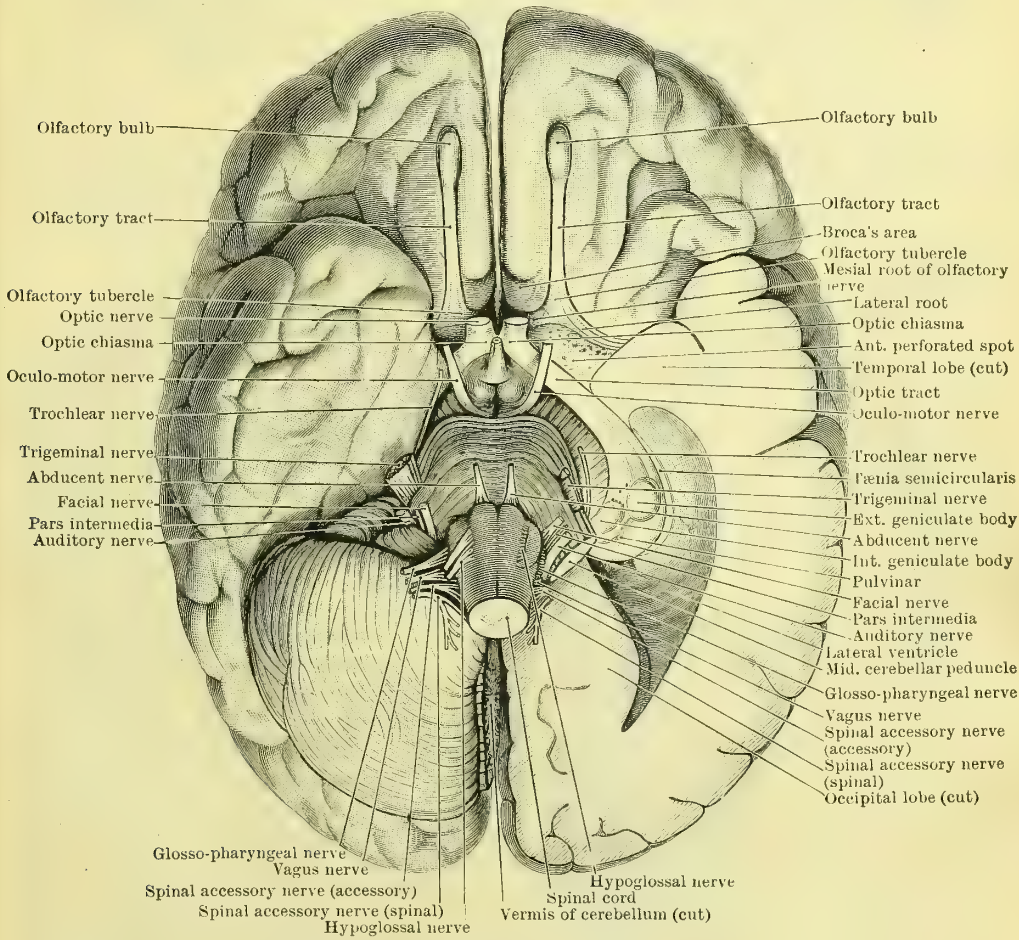


FIG. 452.—VIEW OF THE UNDER SURFACE OF THE BRAIN, with the lower portion of the temporal and occipital lobes, and the cerebellum on the left side removed, to show the origins of the cranial nerves.

connexion with these nerves are also touched upon in the chapter introductory to the Nervous System (p. 414).

THE FIRST OR OLFACTORY NERVE.

The olfactory nerve (n. olfactorius) consists of several parts ; (1) a series of fine

nerves, which arise from (2) the **olfactory bulb**. This again is connected by (3) the **olfactory tract** with the brain, to which it is attached by (4) two **roots** (Fig. 452).

The anatomy of the roots, tract, and bulb of the olfactory nerve are described elsewhere (pp. 528 and 545).

The **olfactory nerves,** about twenty in number, arise from the under surface of the olfactory bulb. The fibres are non-medullated. Piercing the cribriform plate

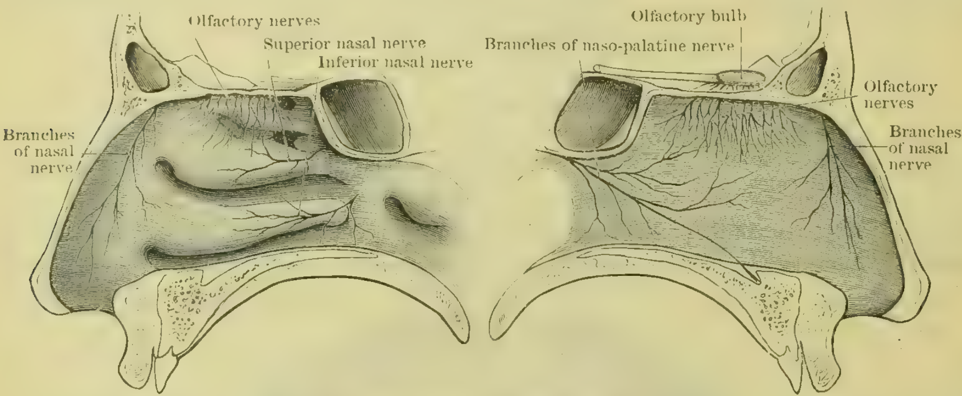


FIG. 453.—INNERVATION OF THE NASAL CAVITY.

of the ethmoid bone, enveloped in sheaths of dura mater, they are distributed in the nasal cavity as the nerves of smell. The fibres form fine plexuses on the upper portion of the nasal septum, and to a less extent over the outer wall of the nose.

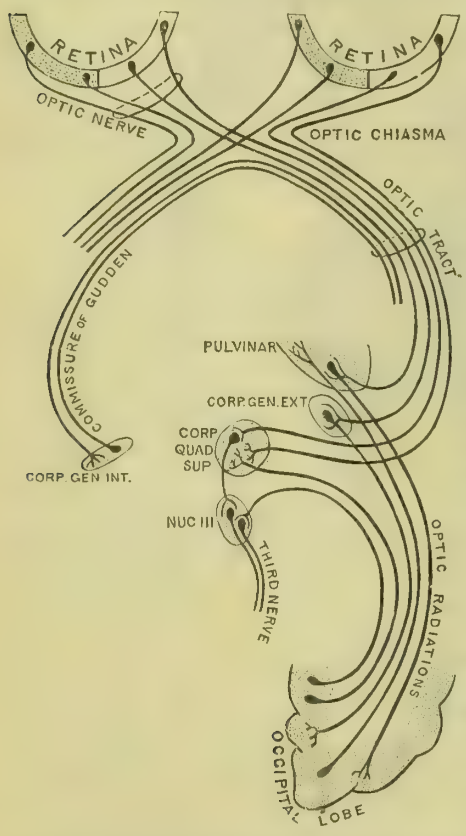


FIG. 454.—DIAGRAM OF THE CENTRAL CONNEXIONS OF THE OPTIC NERVE AND OPTIC TRACT.

THE SECOND OR OPTIC NERVE.

The optic nerve (n. opticus) arises from the brain by means of the **optic tract** (Fig. 452). This takes origin from the external and internal geniculate bodies, situated on the under surface of the optic thalamus at its posterior end, and also from the brachium of the upper of the two corpora quadrigemina (*vide* pp. 510 and 591). The optic tract reaches the base of the brain in the interval between the crus cerebri and the hippocampal convolution of the temporal lobe. The two optic tracts converge in front of the inter-peduncular space, internal to the anterior perforated spot and the termination of the internal carotid artery, to form the **optic chiasma** or **commissure.** This adheres to the under surface of the floor of the third ventricle in front of the tuber cinereum, and gives rise at each end to the **optic nerve**. The optic nerve, directed outwards and forward, pierces the dura mater, and passes from the cranial cavity into the orbit through the optic foramen in company with the ophthalmic artery. In the orbit the nerve is imbedded in the fat behind the eye-ball, and is surrounded by the ocular muscles. It is connected with the eyeball at a point one-eighth of an inch on the inner side of the axis of the eyeball. After piercing the fibrous and vascular coats, the nerve spreads out at the **optic disc** to form the innermost layer of the **retina**. In the orbit the nerve

is crossed by the ophthalmic artery and the nasal nerve, and nearer to its termination it is surrounded by the ciliary vessels and nerves, and by the capsule of Tenon. It is pierced obliquely on its under surface by the central artery of the retina.

Decussation in the Optic Commissure.—In the optic commissure the fibres of the two optic tracts separate, the inner half of each tract decussating to form the mesial half of the opposite optic nerve. The other, outer half of each tract continues its course to form the outer half of the optic nerve on the same side. At the back of the commissure another bundle of fibres is found passing from tract to tract behind the decussating fibres, and known as **Gudden's commissure** (see p. 510).

The Third or Oculo-motor Nerve.

The oculo-motor nerve (n. oculo-motorius) arises from the brain, in the region of the posterior perforated spot, by several radicles emerging from the

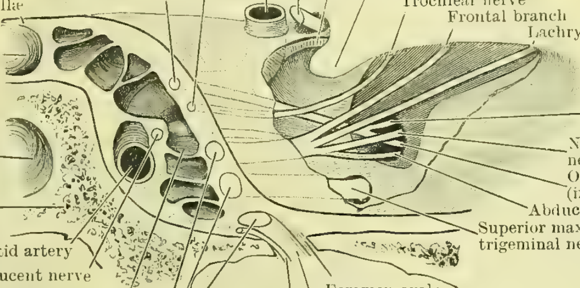


Fig. 455.—Relations of Structures in the Cavernous Sinus and Sphenoidal Fissure.

oculo-motor sulcus, on the inner side of the crus cerebri, just in front of the pons Varolii (Fig. 452). Passing forwards between the posterior cerebral and superior cerebellar arteries, the nerve pierces the dura mater on the outer side of the posterior clinoid process, in a small triangular space between the free and attached borders of the tentorium cerebelli. Beneath the dura mater the nerve courses through the outer wall of the cavernous sinus, and enters the orbit through the sphenoidal fissure and between the two heads of the external rectus muscle. As it enters the orbit it divides into upper and lower branches, separated by the nasal nerve.

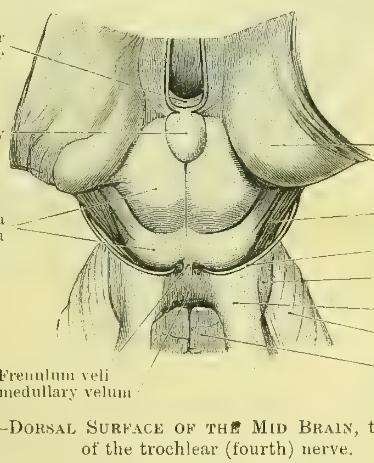


Fig. 456.—Dorsal Surface of the Mid Brain, to show the origin of the trochlear (fourth) nerve.

Branches. — The **superior branch** of the nerve supplies two muscles of the orbit—the superior rectus and the levator palpebræ superioris.

The **inferior branch** passes forwards, and after giving branches to the internal and inferior recti, ends in the inferior oblique muscle. The short root of the ciliary ganglion arises from the terminal branch to the last-named muscle.

Communications.—1. In the cavernous sinus the third nerve communicates with the cavernous plexus on the internal carotid artery. 2. In the cavernous sinus it also

receives a slender communication from the ophthalmic division of the fifth nerve. 3. The **short root of the ciliary ganglion** passes upwards from the branch of the nerve which supplies the inferior oblique muscle.

The Fourth or Trochlear Nerve.

The trochlear nerve (n. trochlearis or patheticus) emerges from the dorsal surface of the mid-brain. It springs at the side of the *frenulum* from the

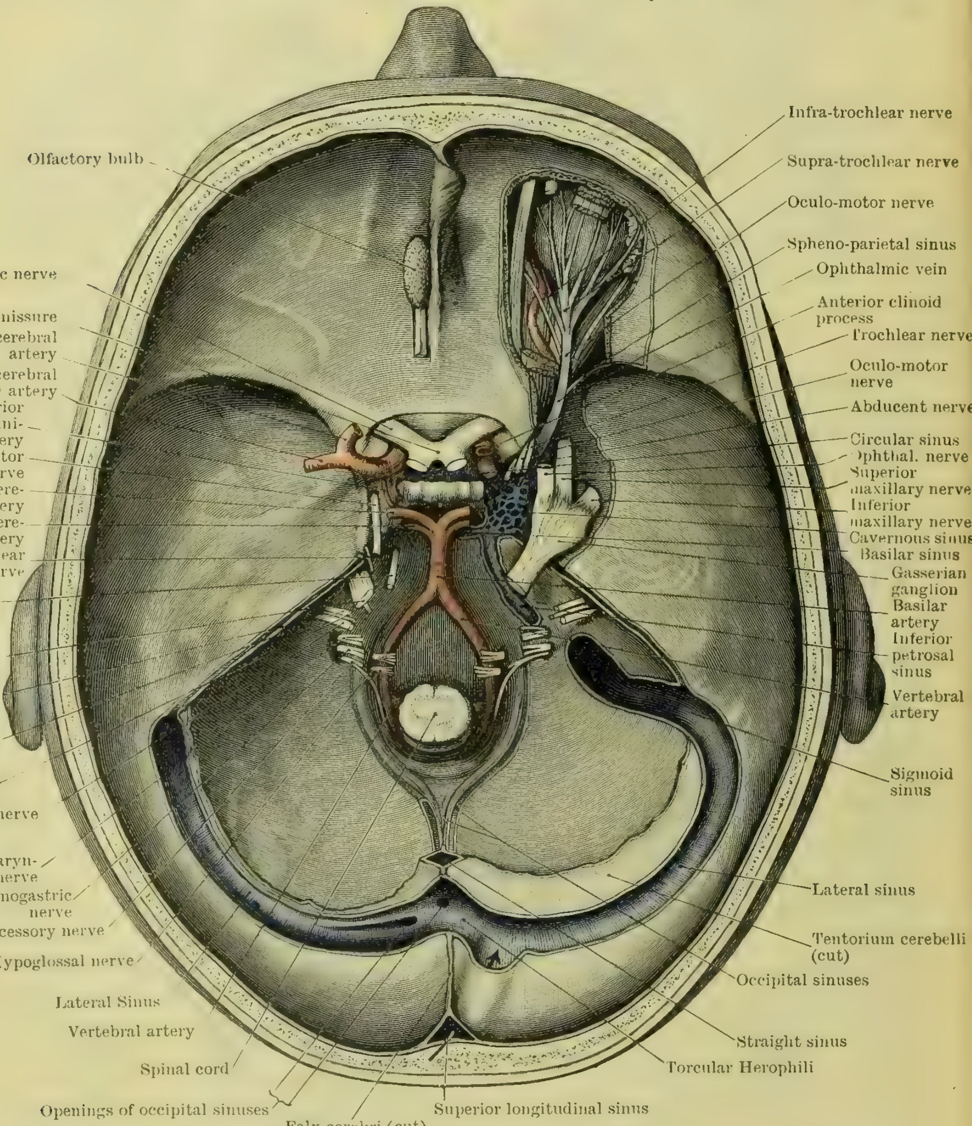


Fig. 457.—The Base of the Skull, to show the dura mater, sinuses, arteries, and nerves.

anterior end of the superior medullary velum, just behind the corpora quadrigemina (for deep origin, see p. 499). It is extremely slender, and of considerable length. Passing round the crus cerebri, the nerve appears in the base of the brain behind the optic tract, in the interval between the crus cerebri internally and the temporal lobe of the cerebrum externally. Continued forwards to the base of the skull, it pierces the free border of the tentorium cerebelli, on the outer side of the third nerve, and proceeds forwards in the outer wall of the cavernous sinus lying between the third and ophthalmic nerves. It enters the orbit through the

sphenoidal fissure, above the muscles of the eyeball, and terminates in the orbital (superior) surface of the superior oblique muscle.

Communications.—In the cavernous sinus the nerve receives (1) a communicating branch from the cavernous or carotid plexus on the internal carotid artery, and (2) a slender filament from the ophthalmic division of the fifth nerve.

The Fifth, Trigeminal or Trifacial Nerve.

The trigeminal nerve (n. trigeminus) arises from the surface of the pons Varolii in its outer part by two roots, a large **sensory root** (portio major) and a small **motor root** (portio minor) (Fig. 452, p. 633). The two roots proceed forwards in the posterior fossa of the base of the skull, and piercing the dura mater beneath the attachment of the tentorium cerebelli to the superior border of the petrous portion of the temporal bone, enter a cavity in the dura mater (cavum Meckelii) over the apex of the petrous bone. The large sensory root gradually conceals the small motor root in its course forwards, and expands beneath the dura mater into a large flattened ganglion,—the **Gasserian ganglion** (ganglion semilunare). This ganglion occupies an impression on the apex of the petrous portion of the temporal bone, and from it three large trunks arise—the ophthalmic or first, the superior maxillary or second, and the inferior maxillary or third divisions of the nerve. The small motor root of the nerve passes forward beneath the Gasserian ganglion, and is wholly incorporated with the inferior maxillary division of the nerve.

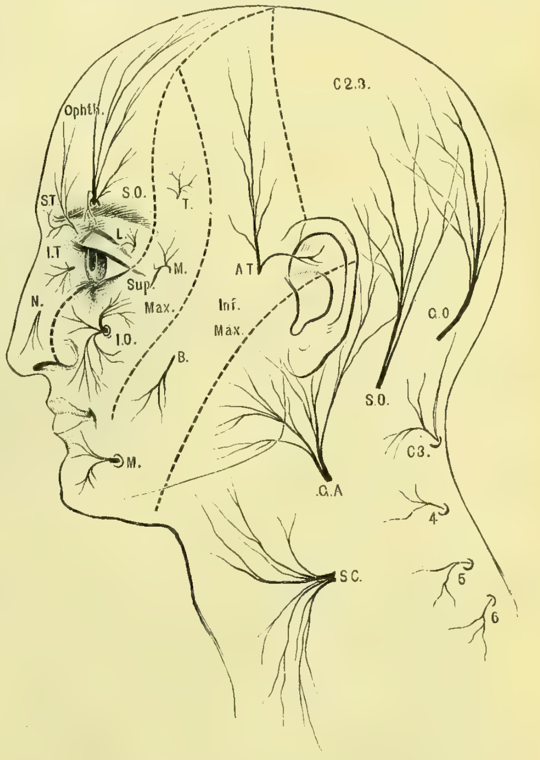


Fig. 458.—Distribution of Sensory Nerves to the Head and Neck.

Ophth, Ophthalmic division of the fifth nerve ; St, Supra-trochlear branch ; S.O, Supra-orbital branch ; I.T, Infra-trochlear branch ; L, Lachrymal branch ; N, External nasal branch ; Sup.Max, Superior maxillary division ; T, Temporal branch ; M, Malar branch ; I.O, Infra-orbital branch ; Inf.Max, Inferior maxillary division ; A.T, Auriculo-temporal branch ; B, Buccal branch ; M, Mental branch ; C2, 3, Branches of the second and third cervical nerves ; G.O, Great occipital nerve ; S.O, Small occipital nerve ; G.A, Great auricular nerve ; S.C, Superficial cervical nerve ; C3, Least occipital nerve ; 4, 5, 6, Posterior primary division of 4th, 5th, and 6th cervical nerves.

Ophthalmic Division (n. ophthalmicus).—The ophthalmic nerve passes forwards to the orbit through the middle fossa of the base of the skull, beneath the dura mater. It lies in the outer wall of the cavernous sinus, at a lower level than the fourth nerve, and reaches the orbit through the sphenoidal fissure (Fig. 455).

In the wall of the cavernous sinus the ophthalmic nerve gives off (1) a small recurrent branch to the dura mater (n. tentorii), (2) communicating branches to the cavernous plexus of the sympathetic on the internal carotid artery, and (3) small communicating twigs to the trunks of the third, fourth, and sixth nerves.

In the sphenoidal fissure the nerve divides into three main branches—lachrymal, frontal, and nasal (Fig. 459).

The **lachrymal nerve** (n. lacrymalis) enters the orbit through the outer angle of the sphenoidal fissure, above the orbital muscles. Passing forwards beneath the periosteum to the anterior part of the orbit, the nerve ends by

supplying branches (*a*) to the lachrymal gland, (*b*) to the conjunctiva, and (*c*) to the skin of the outer canthus of the eye.

The lachrymal nerve *communicates* in the orbit with the orbital branch of the superior maxillary nerve, and on the face, by its terminal branches, with the temporal branches of the facial nerve (Fig. 458).

The **frontal nerve** (n. frontalis), entering the orbital cavity through the sphenoidal fissure, courses forwards above the ocular muscles, and divides at a variable point into two branches—a larger supra-orbital and a smaller supra-trochlear nerve. The **supra-orbital nerve** (n. supra-orbitalis) passes directly forwards, and leaves the orbit through the supra-orbital groove or foramen to reach the forehead. It gives off the following secondary branches: (1) the principal branches (rr. frontales) are distributed to the forehead and scalp, reaching backwards as far as the vertex; (2) small branches supply the upper eyelid; and (3) twigs are distributed to the frontal sinus. On the forehead the supra-orbital nerve communicates with the temporal branches of the facial nerve. The **supra-trochlear nerve** (n. supra-trochlearis) courses obliquely forwards and inwards over the tendon of the superior oblique muscle to reach the inner side of the supra-orbital arch. Leaving the cavity of the orbit, the nerve is distributed to the skin of the mesial part of the forehead, the root of the nose, and the inner canthus of the eye.

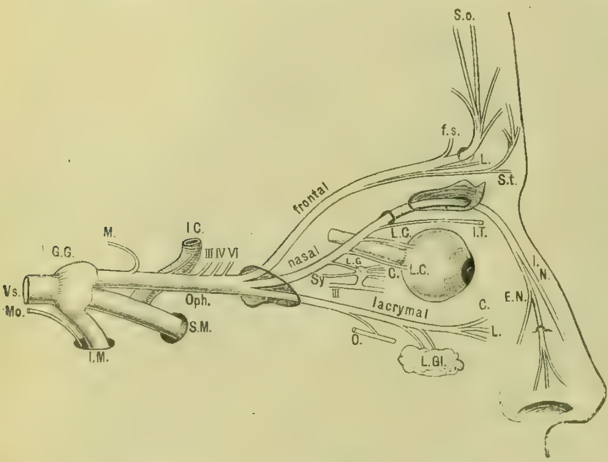


FIG. 459.—SCHEME OF THE DISTRIBUTION OF THE OPHTHALMIC NERVE.

Vs, Trigeminal nerve, afferent root; Mo, Efferent root; G.G, Gasserian ganglion; M, Meningeal branch; I.C, Branch to internal carotid artery; Oph, Ophthalmic nerve; S.M, Superior maxillary nerve; I.M, Inferior maxillary nerve; III, Communication to oculomotor nerve; IV, To trochlear nerve; VI, To abducent nerve. Frontal nerve: f.s, Branches to frontal sinus; S.o, Supra-orbital nerve; S.t, Supra-trochlear nerve; L, Branches to upper eyelid. Nasal nerve; L.G, Long root to lenticular ganglion; Sy, Root from sympathetic (on carotid artery); III, Short root from motor oculi nerve; C, Short ciliary branches; L.C, Long ciliary nerves; I.T, Infra-trochlear nerve; E.N, External, and I.N, Internal nasal nerves. Lachrymal nerve; O, Orbital branch of superior maxillary nerve; L.Gl, Lachrymal gland; C', Conjunctival branch; L, Branch to eyelids and face.

It *communicates* with the infra-trochlear branch of the nasal nerve, either before or after leaving the orbital cavity.

The **nasal nerve** (n. naso-ciliaris) enters the orbit through the sphenoidal fissure, between the heads of the external rectus muscle, and between the two divisions of the third nerve (Fig. 455, p. 635). It crosses the orbital cavity obliquely to reach the anterior ethmoidal foramen, lying in its course below the superior rectus and superior oblique muscles, and above the optic nerve and internal rectus muscle. By the anterior ethmoidal foramen the nerve is transmitted into the cranial cavity, where it lies on the cribriform plate of the ethmoid bone. It enters the nasal cavity through the nasal fissure, and terminates by dividing into internal and external branches. The internal division supplies the mucous membrane over the upper and anterior part of the nasal septum (rr. mediales). The external branch, after supplying collateral offsets to the outer wall of the nose (rr. laterales), finally appears on the face between the nasal bone and lateral cartilage, and supplies branches to the skin of the lower part and tip of the nose.

The **branches** of the nasal nerve may be divided into three sets, arising (*a*) in the orbit, (*b*) in the nose, and (*c*) on the face.

In the orbit the branches are given off in three situations—external to, over, and internal to the optic nerve. (*a*) As the nasal nerve lies external to the optic nerve, it gives off the **long root of the ciliary ganglion** (radix longa). (*b*) As it

crosses the optic nerve **two long ciliary branches** (nn. ciliaris longi) arise, and pass forwards alongside the optic nerve to the eyeball. (*c*) On the inner side of the optic nerve the **infra-trochlear nerve** (n. infra-trochlearis) arises, a slender branch which courses forward beneath the pulley of the superior oblique muscle to the front of the orbit. It ends on the face by supplying the skin of the root of the nose and the eyelids, and communicates either in the orbit or on the face with the supra-trochlear nerve. On the face it also communicates with infra-orbital branches of the facial nerve.

In the nose the **internal nasal branch** supplies the mucous membrane of the fore part of the nasal septum; the **external nasal branch** supplies the fore part of the outer wall of the nose.

On the face the terminal filaments of the nerve are distributed to the skin of the lower half and tip of the nose. The superficial terminal branch communicates with the infra-orbital branches of the facial nerve (Fig. 458).

The **ciliary** or **lenticular ganglion** (ganglion ciliare) is associated with the nasal branch of the ophthalmic nerve and with the lower division of the third nerve. It is a small reddish ganglion, placed between the external rectus muscle

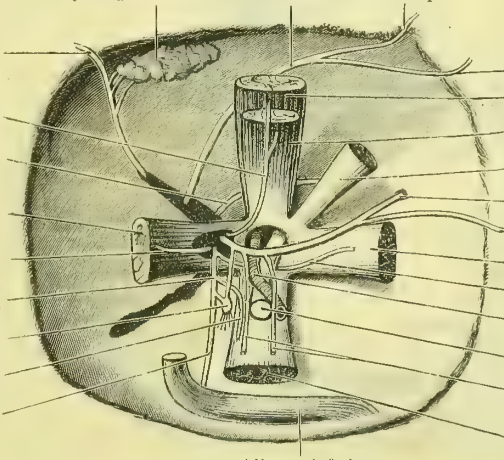


FIG. 460.—SCHEMATIC REPRESENTATION OF THE NERVES WHICH TRAVERSE THE CAVITY OF THE ORBIT.

and the optic nerve, and in front of the ophthalmic artery. Its *roots* are three in number: (1) **sensory** or long (radix longa), derived from the nasal branch of the ophthalmic nerve; (2) **motor** or short (radix brevis), derived from the inferior division of the third nerve; and (3) **sympathetic**, a slender filament from the cavernous plexus on the internal carotid artery, which may exist as an independent root or may be incorporated with the long root from the nasal nerve. The branches from the ganglion are twelve to fifteen **short ciliary nerves** (nn. ciliares breves), which pass to the eyeball in two groups above and below the optic nerve. They supply the coats of the eyeball, including the iris and ciliary muscles. *The circular fibres of the iris* and the *ciliary muscle* are innervated by the third nerve; *the radial fibres of the iris* by the sympathetic.

Superior Maxillary Division of the Fifth Nerve (n. maxillaris).—This large nerve courses forwards from its origin in the Gasserian ganglion through the middle fossa of the base of the skull, beneath the dura mater, and in relation to the lower part of the cavernous sinus (Fig. 455, p. 635). Passing through the foramen rotundum in the root of the pterygoid process, it traverses the spheno-maxillary fossa. It enters the orbit as the infra-orbital nerve, through the spheno-maxillary fissure, and occupying successively the infra-orbital groove and canal, it finally appears on the face through the infra-orbital foramen (Fig. 461).

The branches and communications of this nerve occur (*a*) in the cavity of the cranium, (*b*) in the spheno-maxillary fossa, (*c*) in the infra-orbital canal, and (*d*) on the face.

In the cavity of the cranium the nerve gives off a minute **recurrent branch** (n. meningeus) to the dura mater of the middle fossa of the base of the skull.

In the spheno-maxillary fossa the nerve gives off—(1) two short thick **spheno-palatine nerves** (nn. spheno-palatini), the short or sensory roots of the spheno-palatine (Meckel's) ganglion. (2) A **posterior dental nerve**, which may be double (nn. alveolares superiores), descends through the pterygo-maxillary fissure to the outer side of the upper jaw, and proceeds forwards along the alveolar arch, in company with the posterior dental artery. It supplies the gum and the upper molar teeth by branches which perforate the bone to reach the alveoli. The nerve forms a fine plexus joined by the middle dental nerve before finally reaching the teeth. (3) A small **orbital branch** (n. zygomaticus) enters the orbital cavity through the spheno-maxillary fissure, and proceeding along the outer wall, it communicates with the lachrymal nerve, and passes through the orbital canal in the malar bone, where it divides into malar and temporal branches. The **malar branch** (n. zygomatico-facialis) appears on the face, after traversing the malar bone, and supplies the skin over that bone. It communicates with the malar branches of the facial nerve. The **temporal branch** (n. zygomatico-temporalis) perforates the zygomatic surface of the malar bone, and is distributed, after piercing the temporal fascia, to the skin over the fore part of the temple. It communicates with the temporal branches of the facial nerve. It may be very minute, and not pass further than the temporal fascia, between the two layers of which it may form a communication with the facial nerve. (4) The **infra-orbital nerve** (n. infra-orbitalis) is the terminal branch of the superior maxillary nerve, which enters the orbit through the spheno-maxillary fissure and traverses the infra-orbital canal to reach the face.

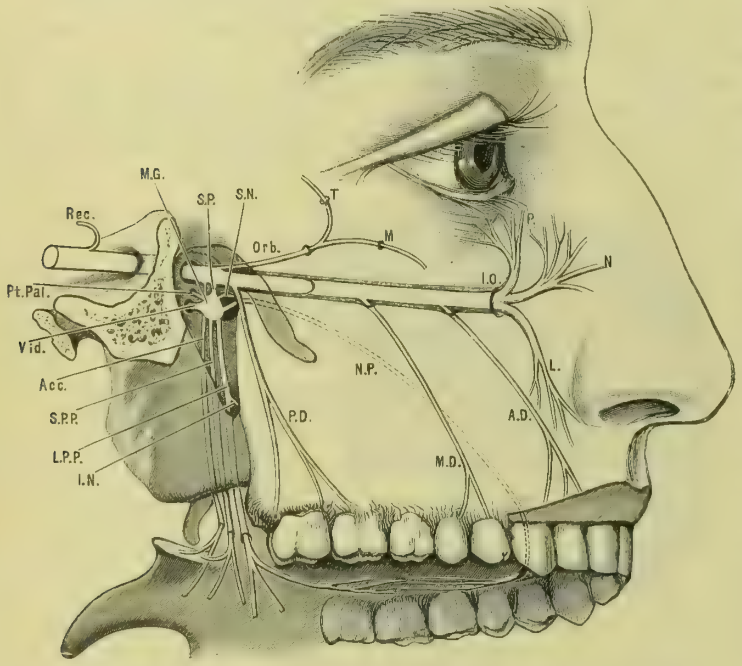


FIG. 461.—SCHEME OF THE COURSE AND DISTRIBUTION OF THE SUPERIOR MAXILLARY NERVE.

Rec, Recurrent branch in the middle fossa of the skull; M.G, Meckel's ganglion in the spheno-maxillary fossa; S.P, Spheno-palatine nerves; S.N, Superior nasal branch; Orb, Orbital nerve; T, Temporal, and M, Malar branches; I.O, Infra-orbital nerve, appearing on the face; P_1 Palpebral; N, Nasal, and L, Labial branches; A.D, Anterior dental branch; M.D, Middle dental branch; N.P, Naso-palatine nerve; P.D, Posterior dental branch; I.N, Inferior nasal branch; L.P.P, Large posterior palatine nerve; S.P.P, Small posterior palatine nerve; Acc, Accessory posterior palatine nerve; Vid, Vidian nerve; Pt.Pal, Pterygo-palatine branch.

In the infra-orbital canal the superior maxillary, now called the infra-orbital nerve, supplies one and sometimes two branches to the teeth—the **middle** and **anterior dental nerves** (rr. alveolares superiores medius and anterior). The former may be only a secondary branch of the latter nerve, or they may arise independently from the infra-orbital nerve. However formed, the nerves descend in bony canals in the wall of the antrum of Highmore (to the lining of which branches are given), and reach the alveolar arch, where they form minute plexuses and supply the teeth (joining posteriorly with the branches of the posterior

dental nerve). The anterior dental nerve supplies the incisor and canine teeth; the middle dental nerve supplies the premolar teeth.

After emerging on the face from the infra-orbital foramen, the infra-orbital nerve divides into a number of radiating branches arranged in three sets—(*a*) **palpebral,** for the lower eyelid; (*b*) **nasal,** for the skin of the side of the nose; and (*c*) **labial,** for the cheek and upper lip. These branches form communications with the infra-orbital branches of the facial nerve, known as the *infra-orbital plexus* (Fig. 458, p. 637).

The **spheno-palatine or Meckel's ganglion** (g. spheno-palatinum) occupies the upper part of the spheno-maxillary fossa. It is a small reddish-gray ganglion, suspended from the superior maxillary nerve by the two **spheno-palatine branches** which constitute its sensory roots. The **motor** and **sympathetic roots** of the ganglion are derived from the **vidian nerve.** This nerve is formed in the cavity of the skull upon the cartilage filling up the foramen lacerum medium, by the union of the *great superficial petrosal nerve* from the geniculate ganglion of the facial nerve (emerging from the temporal bone through the hiatus Fallopii) with the *great deep petrosal nerve,* a branch of the carotid plexus of the sympathetic on the internal carotid artery. The vidian nerve passes through the vidian canal to the spheno-maxillary fossa, where it ends in Meckel's ganglion.

The **branches from the ganglion** are seven in number. (*a*) The **pterygo-palatine** or **pharyngeal** branch passes backwards through the pterygo-palatine canal to supply the mucous membrane of the roof of the pharynx.

(*b*) The **posterior palatine nerves,** three in number, are directed downwards to the palate through the posterior palatine canals. The **large posterior palatine nerve** emerges on the under surface of the palate through the large posterior palatine canal, and at once separates into numerous branches for the supply of the mucous membrane of the soft and the hard palate. Its anterior filaments communicate with branches of the naso-palatine nerve. The main nerve gives off, as it lies in the posterior palatine canal, a small **inferior nasal nerve** which enters the nasal cavity and supplies the mucous membrane of the lower part of the outer wall of the nose. The **small posterior palatine nerve** descends through the small posterior palatine canal, and, piercing the tuberosity of the palate bone, is distributed to the mucous membrane of the soft palate, uvula, and tonsil. It possibly conveys motor fibres to the levator palati and azygos uvulæ muscles. The **accessory posterior palatine nerves** are one or more small twigs which pass through accessory posterior palatine canals, and supply branches to the mucous membrane of the tonsil, soft palate, and uvula.

(*c*) The branches directed inwards from Meckel's ganglion enter the nasal cavity through the spheno-palatine foramen. They are two in number—the naso-palatine and the superior nasal. The **superior nasal nerve** is a small nerve destined for the mucous membrane of the upper and back part of the outer wall of the nose. The **naso-palatine nerve,** after passing through the spheno-palatine foramen, crosses the roof of the nose, and extends obliquely downwards and forwards along the nasal septum, grooving the vomer in its course, to reach the incisor foramen near the front of the hard palate. The nerves pass through the subordinate mesial foramina (of Scarpa), the left nerve in front of the right. In the incisor foramen the two nerves communicate together. They then turn backwards and supply the mucous membrane of the hard palate. They communicate posteriorly with terminal filaments of the large posterior palatine nerves. In its course through the nasal cavity the naso-palatine nerve furnishes collateral branches to the mucous membrane of the roof and septum of the nose (Fig. 453, p. 634).

(*d*) The **orbital branches,** one or more minute branches, pass upwards to the periosteum of the orbit from Meckel's ganglion.

Inferior Maxillary Nerve (n. mandibularis).—The inferior maxillary nerve is formed by the union of two roots: a large **sensory root,** from the Gasserian ganglion, and the small **motor root** of the trigeminal nerve, which is wholly incorporated with this trunk. The two roots pass together beneath the dura mater of the middle fossa of the base of the skull to the foramen ovale, through which they emerge into the pterygoid region. Outside the skull they combine to form a single trunk, which soon separates into anterior and posterior divisions.

At its emergence from the skull the nerve is deeply placed beneath the middle

of the zygomatic arch, and is concealed by the ramus of the lower jaw, and by the temporal, masseter, and external pterygoid muscles.

The branches of the inferior maxillary nerve may be divided into two series—(1) those derived from the undivided nerve, and (2) those derived from the terminal divisions of the nerve.

The branches of the undivided nerve are two in number. (*a*) A small **recurrent branch** (n. spinosus) arises just outside the skull, and accompanying the middle meningeal artery through the foramen spinosum, supplies the dura mater. (*b*) In the pterygoid region a small branch arises for the supply of the **internal pterygoid muscle.** This nerve forms a connexion with the otic ganglion.

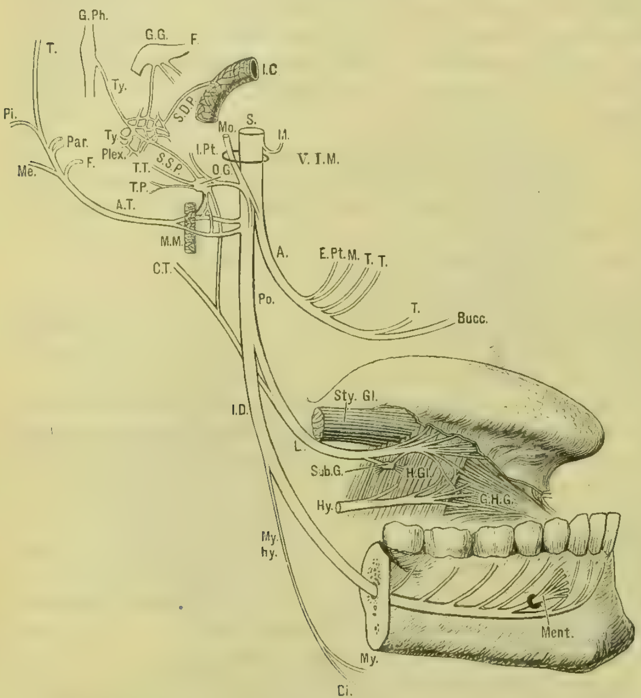


FIG. 462.—SCHEME OF THE DISTRIBUTION OF THE INFERIOR MAXILLARY NERVE.

V.I.M, Inferior maxillary nerve ; S, Afferent, and Mo, Efferent roots ; M, Meningeal branch ; O.G, Otic ganglion ; I.Pt, Nerve to internal pterygoid ; S.S.P, Small superficial petrosal nerve ; T.T, Nerves to tensor tympani, and T.P, Tensor palati ; Ty.Plex, Tympanic plexus ; I.C, Internal carotid artery ; S.D.P, Small deep petrosal nerve ; G.G, Geniculate ganglion ; F, Facial nerve ; Ty, Tympanic branch ; G.Ph, Glossopharyngeal nerve ; M.M, Middle meningeal artery ; A.T, Auriculo-temporal nerve ; F, Communication with facial nerve ; Par, Nerve to parotid gland ; Me, Branch to meatus of ear ; Pi, Branch to pinna ; T, Temporal branch ; A, Anterior division of inferior maxillary nerve ; E.Pt, Nerves to external pterygoid ; M, Masseter ; T.T.T. Temporal, and Bucc, Buccinator muscles ; Po, Posterior division of inferior maxillary nerve ; L, Lingual nerve ; C.T, Chorda tympani nerve ; Sub.G, Sub-maxillary ganglion ; Hy, Hypoglossal nerve ; I.D, Inferior dental nerve ; My.hy, Mylohyoid nerve ; My, Nerve to mylohyoid ; Di, Nerve to digastric (anterior belly) ; Ment, Mental branch ; Sty.Gl, Stylo-glossus ; H.Gl, Hyo-glossus ; G.H.G, Genio-hyoglossus muscles.

The terminal divisions of the nerve are a small anterior and a large posterior trunk.

The small **anterior trunk** passes downwards and forwards beneath the external pterygoid muscle, and separates into the following branches:—(1) A branch for the external pterygoid muscle (n. pterygoideus externus), which supplies it on its deep surface; (2) a branch to the masseter muscle (n. massetericus), which passes over the upper border of the external pterygoid and through the sigmoid notch of the lower jaw; (3) and (4) two branches to the temporal muscle (nn. temporales profundi, anterior et posterior), which also ascend above the external pterygoid muscle; and (5) the **buccal nerve** (n. buccinatorius), which passes obliquely forwards between the two heads of the external pterygoid to reach the buccinator muscle. This nerve is sensory, and its fibres are in part distributed to the skin of the cheek (communicating with buccal branches of the facial nerve); they are also in part distributed to the mucous membrane of the inside of the mouth, to reach which they pierce the fibres of the buccinator muscle. The buccal nerve usually supplies a third branch to the temporal muscle, after emerging between the two heads of the external pterygoid muscle (Fig. 458, p. 637).

The large **posterior trunk** extends downwards a short way beneath the external pterygoid muscle. After giving off by two roots the auriculo-temporal nerve, it ends by dividing into two, the lingual and the inferior dental nerves.

The **auriculo-temporal nerve** (n. auriculo-temporalis) is formed by the union

of two roots which embrace the middle meningeal artery. The nerve passes backwards beneath the external pterygoid muscle and between the internal lateral ligament and the neck of the lower jaw. Entering the substance of the parotid gland, it is directed upwards to the temple over the zygoma in company with the temporal artery. It is finally distributed as a cutaneous nerve of the temple and scalp, and reaches almost to the vertex of the skull.

The auriculo-temporal nerve gives off the following branches:—(1) A small branch to the temporo-maxillary articulation. (2) Branches to the parotid gland. (3) A twig for the supply of the skin of the external auditory meatus (and membrana tympani). (4) Branches to the upper half of the pinna on its outer aspect. (5) Terminal branches to the skin of the temple and scalp.

It has the following **communications** with other nerves:—(1) Important communications are effected by the roots of the nerve, which are separately joined by small branches from the otic ganglion. (2) The parotid branches of the nerve are connected with branches of the facial nerve in the substance of the gland. (3) The temporal branch of the nerve is in communication superficially with the temporal branches of the facial nerve.

The **lingual nerve** (n. lingualis) is the smaller of the two terminal branches of the posterior division of the inferior maxillary nerve. It proceeds downwards in front of the inferior dental nerve, beneath the external pterygoid muscle, to its lower border. After passing between the internal pterygoid muscle, and the ramus of the lower jaw, it crosses beneath the mucous membrane of the floor of the mouth in the interval between the mylohyoid and hyoglossus muscles and beneath the duct of the submaxillary gland. It sweeps forwards and inwards to the side of the tongue, to the mucous membrane over the anterior two-thirds of which it is distributed.

Two nerves communicate with the lingual nerve in its course to the tongue:—(1) The **chorda tympani branch** of the facial nerve joins it beneath the external pterygoid muscle, and is incorporated with it in its distribution to the tongue. (2) The **hypoglossal nerve** forms larger or smaller loops of communication with the lingual nerve as they course forwards together over the hyoglossus muscle.

Besides supplying the aforesaid branches to the mucous membrane over the sides and dorsum of the tongue in its anterior two-thirds, the lingual nerve supplies the mucous membrane of the outer wall and floor of the mouth. It also assists, along with the chorda tympani nerve, in forming the roots of the submaxillary ganglion.

The **submaxillary ganglion** (ganglion submaxillare) is a minute reddish ganglion placed on the hyoglossus muscle, between the lingual nerve and the duct of the submaxillary gland. It is suspended from the former by two trunks, consisting for the most part of fibres of the lingual and chorda tympani nerves which at this point become separated from the lingual nerve and incorporated with the ganglion. The **roots** of the ganglion are—(1) an afferent root, derived from the lingual nerve; (2) an efferent root, derived from the chorda tympani; and (3) a sympathetic root, from the sympathetic plexus upon the facial artery.

The **branches from the ganglion** are distributed to the submaxillary gland and Wharton's duct, and by fibres which become reunited with the trunk of the lingual nerve, to the sublingual gland.

The **inferior dental nerve** (n. alveolaris inferior) is larger than the lingual nerve. It passes from beneath the lower border of the external pterygoid muscle to reach the interval between the ramus and internal lateral ligament of the lower jaw. Entering the inferior dental canal through the inferior dental foramen, it traverses the substance of the ramus and body of the lower jaw, distributing branches in its course to the teeth. A fine plexus is formed by the dental branches before they finally supply the teeth.

Branches and Communications.—(1) The **mylohyoid nerve** is a small branch arising just before the inferior dental nerve passes through the inferior dental foramen. Grooving the ramus of the jaw in its course, it descends into the submaxillary triangle on the superficial aspect of the mylohyoid muscle. Concealed in this situation by the submaxillary gland and the facial artery, it is distributed

to the mylohyoid and anterior belly of the digastric muscles. (2) The **mental branch** of the inferior dental nerve is a trunk of considerable size arising from the main nerve in the inferior dental canal. It emerges from the lower jaw through the mental foramen, and is distributed by many branches to the chin and lower lip. It communicates beneath the facial muscles with the supra-mandibular branches of the facial nerve (Fig. 458, p. 637). (3) The **incisor branch** is the terminal part of the inferior dental nerve remaining after the origin of the mental branch. It supplies the incisor and canine teeth.

The **otic ganglion** (g. oticum) is situated beneath the inferior maxillary nerve just below the foramen ovale. Like the other ganglia described above, it possesses three roots :—(1) A *motor root,* derived from the nerve to the internal pterygoid muscle ; (2) a *sensory root,* formed by the *small superficial petrosal nerve* from the tympanic plexus (through which communications are effected with the tympanic branch of the glosso-pharyngeal nerve, and a branch from the geniculate ganglion of the facial nerve) ; (3) a *sympathetic root,* from the plexus on the middle meningeal artery (Fig. 462).

Five branches arise from the ganglion—three communicating and two motor branches. The three **communicating nerves** are fine branches which join respectively the vidian nerve, the roots of the auriculo-temporal, and the chorda tympani nerve. The two **motor nerves** supply the tensor tympani and tensor palati muscles.

Summary.—The trigeminal, the largest and most complex of the cranial nerves, is (1) the chief sensory nerve for the face, the anterior half of the scalp, the orbit and eyeball, the nose and nasal cavity, the lips, teeth, mouth, and two-thirds of the tongue ; (2) the motor fibres of the nerve supply the muscles of mastication, the mylohyoid and anterior belly of the digastric, possibly the levator palati and azygos uvulæ (through Meckel's ganglion), and the tensor tympani and tensor palati muscles (through the otic ganglion) ; (3) through the ganglia placed on the three divisions of the nerve, not only are important organs, areas, and muscles innervated, but communications are also effected with the sympathetic system, with the third nerve (lenticular ganglion), facial nerve (spheno-palatine and otic ganglia), and glosso-pharyngeal nerve (otic ganglion).

In its distribution to the skin of the face the branches of the fifth nerve present two striking peculiarities :—(1) While the branches to the skin reach the surface at many points and in diverse ways, the three main divisions are severally, by their branches, responsible for the supply of three clearly demarcated cutaneous areas. (2) By numerous communications with the facial nerve, sensory fibres are given to the muscles of expression supplied by the facial nerve.

The Sixth or Abducent Nerve.

The abducent nerve (n. abducens) issues from the brain at the lower border of the pons Varolii, just above the pyramid of the medulla oblongata (for deep origin, see p. 484). It is directed forwards, and pierces the dura mater of the posterior fossa of the base of the skull alongside the dorsum sellæ (Fig. 457, p. 636). It then occupies the inner wall of the cavernous sinus, and is placed on the outer side of the internal carotid artery. It passes through the sphenoidal fissure below the third and nasal nerves and between the two heads of the external rectus muscle (Fig. 455, p. 635). In the cavity of the orbit it supplies the external rectus muscle on its inner (ocular) surface.

Communications.—In the wall of the cavernous sinus the sixth nerve receives two communicating filaments :—(1) From the carotid plexus of the sympathetic, and (2) from the ophthalmic division of the trigeminal nerve.

The Seventh or Facial Nerve.

The facial nerve (n. facialis) emerges from the brain at the posterior border of the pons Varolii, below the trigeminal nerve and internal to the auditory nerve (for deep origin, see p. 482). Between it and the latter nerve is the minute **pars intermedia** of Wrisberg (Fig. 452, p. 633). The nerve passes outwards through the internal auditory meatus, courses through the aqueduct of Fallopius in the petrous portion of the temporal bone, emerges in the base of the skull by the stylo-mastoid foramen, and passes forwards through the parotid gland to supply the muscles of the face. *In the internal auditory meatus* the nerve is placed upon the auditory nerve, the

pars intermedia intervening. *In the aqueduct of Fallopius* the nerve first passes backwards on the inner side of the tympanum, and then downwards behind the tympanum, in the inner wall of the tympanic antrum. *In the parotid gland* the nerve crosses superficially the external carotid artery and the temporo-maxillary vein. *On the face* its branches radiate from the anterior border of the parotid gland and enter the deep surface of the facial muscles.

Branches and Communications.—(i.) *In the internal auditory meatus* the *pars intermedia* (n. intermedius), lying between the facial and auditory nerves, sends communicating branches to both. The branch to the auditory nerve probably separates from it again to join the geniculate ganglion of the facial nerve.

(ii.) *In the aqueduct of Fallopius* the **geniculate ganglion** (g. geniculi) is formed at the point where the facial nerve bends backwards (geniculum n. facialis). It is an oval swelling on the nerve, and is joined by a branch from the upper (vestibular) trunk of the auditory nerve, by which it probably receives fibres of the *pars intermedia*. From the ganglion three small nerves arise:—(1) The **large superficial petrosal nerve** passes forwards through the hiatus Fallopii to the middle fossa of the base of the skull. On the upper surface of the foramen lacerum medium it is joined by the **great deep petrosal nerve** from the sympathetic plexus on the internal carotid artery to form the **vidian nerve**, which, after traversing the vidian canal, ends in Meckel's ganglion. (2) A minute nerve pierces the temporal bone and joins the tympanic branch of the glosso-pharyngeal in the substance of the bone. By their union the **small superficial petrosal nerve** is formed, which pierces the temporal bone and ends in the otic ganglion. (3) The **external superficial petrosal nerve** is a minute inconstant branch which joins the sympathetic plexus on the middle meningeal artery.

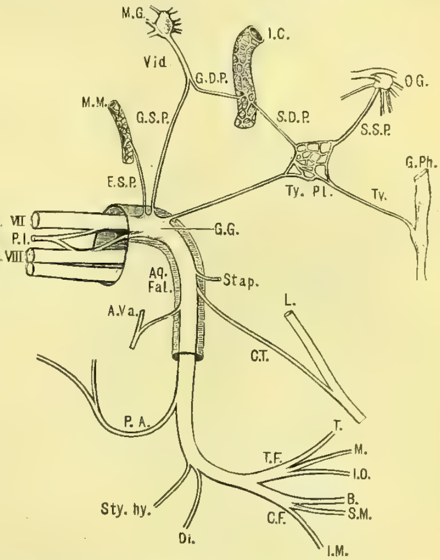


FIG. 463.—THE FACIAL NERVE WITH ITS BRANCHES AND COMMUNICATIONS IN THE AQUEDUCT OF FALLOPIUS.

VII, Facial nerve; P.I, Pars intermedia; VIII, Auditory nerve; Aq.Fal, Aqueduct of Fallopius; G.G, Geniculate ganglion; E.S.P, External superficial petrosal nerve; M.M, Middle meningeal artery; G.S.P, Great superficial petrosal nerve: G.P.D, Great deep petrosal nerve; I.C, Internal carotid artery; Vid, Vidian nerve; M.G, Meckel's ganglion; Ty.Pl, Tympanic plexus; S.D.P, Small deep petrosal nerve; G.Ph, Glosso-pharyngeal nerve; Ty, Tympanic branch; S.S.P, Small superficial petrosal nerve; O.G, Otic ganglion; Stap, Nerve to stapedius; C.T, Chorda tympani nerve; L, Lingual nerve; A.Va, Communication with auricular branch of vagus; P.A, Posterior auricular nerve; Sty.hy, Nerve to stylo-hyoid; Di, Nerve to digastric (posterior belly); T.F, Temporo-facial division; C.F, Cervico-facial division; T, Temporal; M, Malar; I.O, Infra-orbital; B, Buccal; S.M, Supra-mandibular, and I.M, Infra-mandibular branches.

In the course of the facial nerve in the lower part of the aqueduct of Fallopius, behind the tympanum, three branches arise—(1) The small nerve to the **stapedius muscle**, which passes forwards to the tympanum. (2) The **chorda tympani nerve** (probably associated with the *pars intermedia*), which enters the tympanic cavity through the *iter chordæ posterius*, passes over the membrana tympani and the handle of the malleus, and leaves the cavity through the *iter chordæ anterius* to reach the pterygoid region. Beneath the external pterygoid muscle it becomes incorporated with the lingual branch of the inferior maxillary nerve, and in its further course is inseparable from that nerve. It supplies a root to the submaxillary ganglion, and is finally distributed (probably as the nerve of taste) to the side and dorsum of the tongue in its anterior two-thirds. The chorda tympani nerve receives beneath the external pterygoid muscle a fine communication from the otic ganglion. (3) Before it leaves the aqueduct of Fallopius a fine **communicating branch** arises from the facial nerve to join the auricular branch of the pneumogastric nerve.

iii. *In the neck* the facial nerve gives off three muscular branches: (1) and (2) small branches supply the stylo-hyoid and the posterior belly of the digastric, the latter nerve sometimes communicating with the glosso-pharyngeal. (3) The **posterior auricular nerve** bends backwards and upwards over the anterior border of the mastoid process along with the posterior auricular artery. It divides into two branches—an *auricular branch* for the retrahens aurem and the intrinsic muscles of the pinna, and an *occipital branch* for the posterior belly of the occipito-frontalis muscle. The posterior auricular nerve communicates with the great auricular, small occipital, and auricular branch of the pneumogastric nerves in its course.

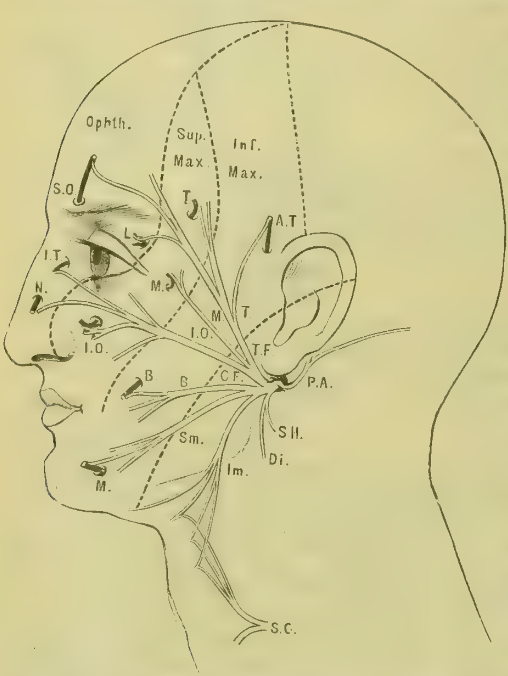


Fig. 464.—Distribution of Facial Nerve outside the Skull, and Communications with Trigeminal Nerve on the Face.

Facial nerve.—P.A, Posterior auricular nerve; S.H, Nerve to stylohyoid; Di, Nerve to digastric (posterior belly); T.F, Temporo-facial division; T, Temporal; M, Malar; I.O, Infra-orbital branches; C.F, Cervico-facial division; B, Buccal; Sm, Supra-mandibular; Im, Infra-mandibular branches.

Trigeminal nerve.—Ophth, Ophthalmic division; S.O, Supra-orbital; I.T, Infra-trochlear; N, External nasal; L, Lachrymal branches. Sup.Max, Superior maxillary division; T, Temporal; M, Malar; I.O, Infra-orbital branches. Inf.Max, Inferior maxillary division; A.T, Auriculo-temporal; B, Buccal; M, Mental branches; S.C, Superficial cervical nerve.

iv. *In the parotid gland* the facial nerve spreads out in an irregular series of branches (**pes anserinus**), indefinitely divided into a temporo-facial and a cervico-facial division. Communications occur in the substance of the gland between the main trunks and the great auricular and auriculo-temporal nerves.

The **temporo-facial division** gives off three series of subordinate branches which radiate forwards and upwards from the parotid gland.

1. The **temporal branches** are of large size, and, sweeping out of the parotid gland over the zygomatic arch, are distributed to the orbicularis palpebrarum, frontalis, corrugator supercilii, attrahens, and attollens aurem. The temporal branches communicate in their course with the ~~auriculo-temporal~~ ~~(of the~~ superior maxillary), lachrymal, and supra-orbital branches of the trigeminal nerve.

2. The **malar branches** are small, and sometimes are inseparable from the temporal or infra-orbital nerves. Extending forwards across the malar bone, they supply the orbicularis palpebrarum and zygomatic muscles, and communicate with the malar branch of the superior maxillary nerve.

3. The **infra-orbital branches** are of considerable size. Passing forwards over the masseter muscle in company with Stenson's duct, they supply the orbicularis palpebrarum, the zygomatici, buccinator, and the muscles of the nose and upper lip. The **infra-orbital plexus** is formed by the union of these nerves with the infra-orbital branch of the superior maxillary nerve below the lower eyelid. Smaller communications occur with the infra-trochlear and nasal nerves on the side of the nose.

The **cervico-facial division** of the facial nerve also supplies three series of secondary branches.

1. The **buccal branch** (or branches) extends forwards to the angle of the mouth to supply the muscles converging to the mouth, including the buccinator. It communicates with the buccal branch of the inferior maxillary nerve in front of the anterior border of the masseter muscle.

2. The **supra-mandibular branch** passes along the lower jaw to the interval

between the lower lip and chin, and supplies the depressor anguli oris, depressor labii inferioris, and orbicularis oris. It communicates with the mental branch of the inferior dental nerve.

3. The **infra-mandibular branch** emerges from the parotid gland near its lower end, and sweeps forwards below the angle of the jaw to the front of the neck. It supplies the platysma myoides, and forms loops of communication with the superficial cervical nerve from the cervical plexus.

The Eighth or Auditory Nerve.

The auditory nerve (n. acusticus) arises from the brain by two roots, mesial and lateral. The **mesial root** (radix vestibularis) emerges between the olive and the restiform body. The **lateral root** (radix cochlearis), continuous through the cochlear nucleus with the striæ acusticæ of the fourth ventricle, winds round the outer side of the restiform body (for deep connexions, see p. 480). The two roots become incorporated to form the trunk of the nerve, which is attached to the brain on the outer side of the facial nerve and pars intermedia at the posterior border of the pons Varolii (Fig. 452, p. 633).

The nerve extends outwards through the internal auditory meatus, lying beneath the facial nerve and pars intermedia (Fig. 457, p. 636). In the meatus its two component parts separate from one another, forming a superior or vestibular trunk continuous with the mesial root, and an inferior or cochlear trunk continuous with the lateral root. These trunks again subdivide, and piercing the lamina cribrosa, supply the several parts of the labyrinth.

The **superior** or **vestibular trunk** (n. vestibuli) in the internal auditory meatus usually receives fibres from the *pars intermedia*, and gives off a communicating branch to the geniculate ganglion of the facial nerve. It then separates into three terminal branches which pierce the lamina cribrosa and supply (1) the macula acustica of the **utricle**, and the ampullæ of (2) the **superior** and (3) **external semicircular canals.**

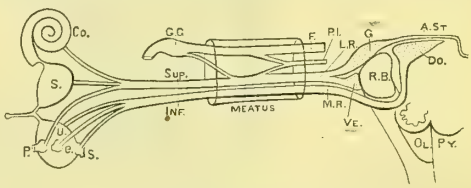


Fig. 465.—Scheme of the Origin and Distribution of the Auditory Nerve.

Py, Pyramid; Ol, Olive; R.B, Restiform body; A.St, Striæ acusticæ; Do, Dorsal nucleus; G, Lateral cochlear nucleus; Ve, Ventral nucleus; L.R, Lateral root, and M.R, Median root of auditory nerve; P.I, Pars intermedia; F, Facial nerve; G.G, Geniculate ganglion; Sup, Superior (cochlear), and Inf, Inferior (vestibular) branches of auditory nerve; Co, Cochlea; S, Saccule; P, Posterior semicircular canal; *e*, External semicircular canal; S, Superior semicircular canal; U, Utricle.

The **inferior** or **cochlear trunk** (n. cochleæ) gives off branches (1) to the macula acustica of the **saccule**, (2) to the ampulla of the **posterior semicircular canal**, and (3) is continued through the lamina cribrosa to the labyrinth as the **cochlear nerve**, which is distributed through the modiolus and osseous spiral lamina to the organ of Corti in the cochlea.

Both the vestibular and cochlear nerves contain among their fibres collections of nerve cells, forming in each nerve a distinct ganglion—the **vestibular ganglion** (g. vestibulare) on the vestibular trunk, and the **spiral ganglion of the cochlea** (g. spirale) on the cochlear trunk.

The Ninth or Glosso-pharyngeal Nerve.

The glosso-pharyngeal nerve (n. glosso-pharyngeus) (Fig. 452, p. 633) arises from the brain by five or six fine radicles which emerge from the medulla oblongata between the olive and the restiform body, close to the facial nerve above, and in series with the roots of the pneumogastric nerve below (for deep connexions, see p. 478). The rootlets combine to form a nerve which extends outwards to the jugular foramen, through which it passes, along with the pneumogastric and spinal accessory nerves, but enveloped in a separate sheath of dura mater (Fig. 457, p. 636). Reaching the neck, the nerve arches downwards and forwards to the interval between the hyoid bone and the lower jaw. It lies at first between the internal carotid artery and the internal jugular vein, and then between the internal and external carotid

arteries, in its course to the side of the pharynx. It sweeps round the stylo-pharyngeus muscle and the stylo-hyoid ligament, and disappears beneath the hyoglossus muscle, to reach its termination in the tongue.

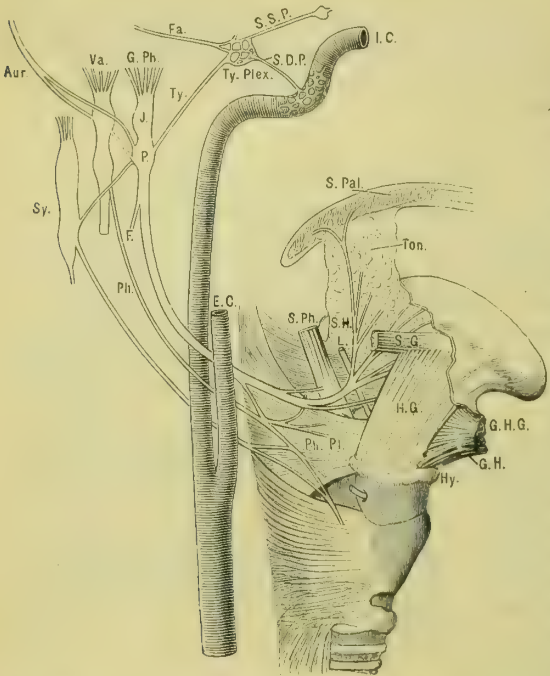


FIG. 466.—SCHEME OF THE DISTRIBUTION OF THE GLOSSO-PHARYNGEAL NERVE.

G.Ph, Glosso-pharyngeal nerve ; J, Jugular, and P, Petrous ganglia ; Ty, Tympanic branch (Jacobson's nerve) ; Ty.Plex, Tympanic plexus ; Fa, Root from geniculate ganglion of facial nerve ; S.S.P, Small superficial petrosal nerve to the otic ganglion ; S.D.P, Small deep petrosal nerve ; I.C, Internal carotid artery ; Va, Pneumogastric nerve ; Aur, Auricular branch (Arnold's nerve) ; Sy, Superior cervical sympathetic ganglion ; F, Communicating branch to facial nerve ; Ph, Pharyngeal branch of vagus ; E.C, External carotid artery ; Ph.Pl, Pharyngeal plexus ; S.Ph, Stylo-pharyngeus muscle ; S.H.L, Stylo-hyoid ligament ; H.G, Hyo-glossus ; S.G, Stylo-glossus ; Ton, Tonsil ; S.Pal, Soft palate ; G.H.G, Genio-hyoglossus ; G.H, Genio-hyoid ; Hy, Hyoid bone.

The branches of the nerve may be classified in three series, according to their origin—(i.) in the jugular foramen ; (ii.) in the neck ; (iii.) in relation to the tongue.

In the jugular foramen there are two enlargements upon the trunk of the nerve—the jugular and petrous ganglia. The **jugular ganglion** (g. superius) is small, does not implicate the whole width of the nerve, and may be fused with the petrous ganglion, or even absent altogether. No branches arise from it.

The **petrous ganglion** (g. petrosum) is distinct and constant. It is placed upon the nerve at the lower part of its course through the jugular foramen.

Branches and Communications of the Petrous Ganglion.—The **tympanic branch** (n. tympanicus, Jacobson's nerve) is the most important offset from this ganglion. It passes through a small canal in the bridge of bone between the jugular foramen and the carotid canal to reach the cavity of the tympanum, where it breaks up into branches, to form, along with branches from the carotid plexus of the sympathetic on the internal carotid artery (**small deep petrosal nerve**), the **tympanic plexus** for the supply of the mucous lining of the tympanum, mastoid cells, and Eustachian tube (Fig. 463, p. 645). The fibres of the tympanic branch of the glosso-pharyngeal nerve become reunited to form, by their union with a small nerve from the geniculate ganglion of the facial nerve, the **small superficial petrosal nerve** in the substance of the temporal bone. This passes forwards through the temporal bone, and eventually joins the otic ganglion.

Besides forming the tympanic branch, the petrous ganglion of the glosso-pharyngeal nerve communicates with three other nerves—(1) with the superior cervical ganglion of the sympathetic ; (2) with the auricular branch of the pneumogastric ; and (3) sometimes with the ganglion of the root of the pneumogastric.

In the neck the glosso-pharyngeal nerve gives off two branches. (1) As it crosses over the **stylo-pharyngeus muscle** it supplies the nerve to that muscle, which sends fibres through it to reach the mucous membrane of the pharynx. (2) The **pharyngeal branches** of the nerve supply the mucous membrane of the pharynx directly, after piercing the superior constrictor muscle, and indirectly, after joining, along with the pharyngeal offsets from the pneumogastric and the superior cervical ganglion of the sympathetic, in the formation of the **pharyngeal plexus**.

The **terminal branches** of the nerve supply the mucous membrane of the tongue and adjacent parts. A **tonsillitic branch** forms a plexus (circulus tonsillaris)

to supply the mucous membrane covering the tonsil, the adjacent part of the soft palate, and the pillars of the fauces. **Lingual branches** supply the mucous membrane of the dorsal third and lateral half of the tongue, extending backwards to the glosso-epiglottidean folds and the front of the epiglottis.

The Tenth or Pneumogastric Nerve.

The pneumogastric or vagus nerve (n. vagus) arises from the brain by numerous radicles attached to the front of the restiform body of the medulla oblongata, in series with the glosso-pharyngeal nerve above and the spinal accessory nerve below it (for deep connexions, see p. 478). Uniting to form a single trunk, the roots of the nerve pass outwards to the jugular foramen, through which they emerge into the neck.

In the jugular foramen the nerve occupies the same sheath of dura mater as the spinal accessory nerve, and is placed behind the glosso-pharyngeal nerve. Two ganglia are present on the trunk in this situation. The higher and smaller is the **ganglion of the root** (g. jugulare); the lower and larger is the **ganglion of the trunk** of the nerve (g. nodosum).

In the neck the pneumogastric nerve pursues a vertical course in front of the spinal column. It occupies the carotid sheath, lying between and behind the internal and common carotid arteries and the internal jugular vein. It enters the thorax behind the large veins: *on the right side,* after crossing over the subclavian artery; *on the left side,* in the interval between the left common carotid and subclavian arteries.

In the thorax the nerves occupy the superior and posterior media-

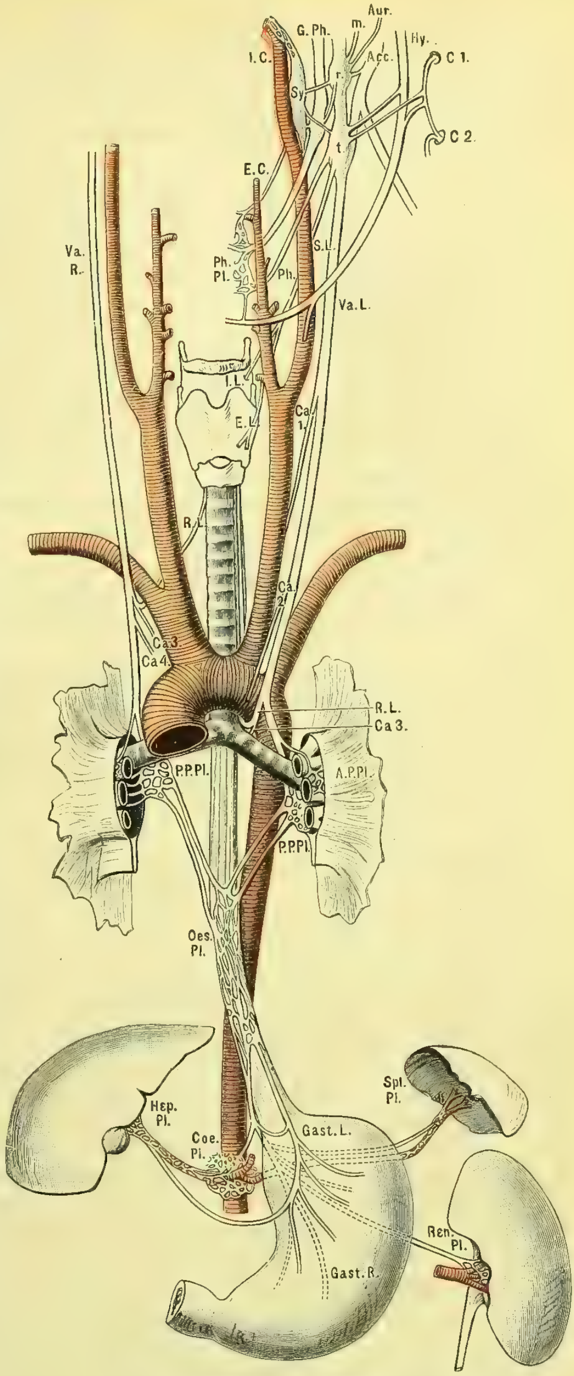


Fig. 467.—The Distribution of the Pneumogastric Nerve.

Va.R, Va.L, Right and left vagi; r, Ganglion of the root and connexions with Sy, Sympathetic, superior cervical ganglion; G.Ph, Glosso-pharyngeal; Acc, Spinal accessory nerve; m, Meningeal branch: Aur, Auricular branch; t, Ganglion of the trunk and connexions with Hy, Hypoglossal nerve; C1, C2, Loop between the first two cervical nerves; Sy, Sympathetic; Acc, Spinal accessory nerve; Ph, Pharyngeal branch; Ph.Pl, Pharyngeal plexus; S.L, Superior laryngeal nerve; I.L, Internal laryngeal branch; E.L, External laryngeal branch; I.C, Internal, and E.C, External carotid arteries; Ca1, Superior cervical cardiac branch; Ca2, Inferior cervical cardiac branch; R.L, Recurrent laryngeal nerve; Ca3, Cardiac branches from recurrent laryngeal nerves; Ca4, Thoracic cardiac branch (right vagus); A.P.Pl, Anterior, and P.P.Pl, Posterior pulmonary plexuses; Oes.Pl, Œsophageal plexus; Gast.R, and Gast.L, Gastric branches of vagus (right and left); Coe.Pl, Cœliac plexus; Hep.Pl, Hepatic plexus; Spl.Pl, Splenic plexus; Ren.Pl, Renal plexus.

stinal spaces, and their relations are different on the two sides. (*a*) *In the superior mediastinum* the *right nerve* continues its course alongside the innominate artery and the trachea, and behind the right innominate vein and superior vena cava, to the back of the root of the lung. The *left nerve* courses downwards between the left common carotid and subclavian arteries, and behind the left innominate vein and the phrenic nerve. It passes over the aortic arch, and then proceeds to the back of the root of the left lung. (*b*) *In the posterior mediastinum* the pneumogastric nerves are concerned in the formation of two great plexuses—the pulmonary and the œsophageal. Behind the root of each lung the nerve breaks up to form the large **posterior pulmonary plexus**, from the lower end of which two nerves emerge on each side. These nerves on the right side pass obliquely over the vena azygos major; on the left side they cross the thoracic aorta. Both series reach the œsophagus, and divide into small anastomosing branches which form the **œsophageal plexus.** At the œsophageal opening of the diaphragm the two nerves become separated from the plexus, and entering the abdomen—the left nerve in front of the œsophagus, the right nerve behind it—they terminate by supplying the stomach and other abdominal organs.

The communications and branches of the pneumogastric nerve may be described as (i.) ganglionic, (ii.) cervical, (iii.) thoracic, and (iv.) abdominal (Fig. 467).

The **ganglion of the root** (g. jugulare) is small and spherical. It occupies the jugular foramen, and gives off two branches—meningeal and auricular.

The **meningeal branch** passes backwards to supply the dura mater of the posterior fossa of the base of the skull.

The **auricular branch** (Arnold's nerve) ascends to the ear in a fissure between the jugular and stylo-mastoid foramina. It receives near its origin a twig from the tympanic branch of the glosso-pharyngeal nerve, and usually communicates with the facial nerve by a branch arising from the latter in the aqueduct of Fallopius. The nerve is distributed to the back of the pinna and the external auditory meatus, and communicates superficially with the posterior auricular nerve.

Communications.—Besides supplying the meningeal and auricular branches, the ganglion of the root of the pneumogastric nerve receives communications from (1) the superior cervical ganglion of the sympathetic; (2) the spinal accessory nerve; and (3) the petrous ganglion of the glosso-pharyngeal nerve (sometimes).

The **ganglion of the trunk** of the nerve (g. nodosum), placed immediately below the preceding, is large and fusiform. Like the previous ganglion, it supplies two branches—the pharyngeal and superior laryngeal nerves.

The **pharyngeal branch** receives its fibres (through the ganglion) from the spinal accessory nerve. It passes obliquely downwards and inwards to the pharynx between the internal and external carotid arteries, and combines with the pharyngeal nerves from the glosso-pharyngeal and superior cervical ganglion of the sympathetic to form the **pharyngeal plexus.** From this plexus the muscles of the pharynx and soft palate (except the stylo-pharyngeus and tensor palati) are supplied. The **lingual branch** is a small nerve which separates itself from the plexus and joins the hypoglossal nerve in the anterior triangle of the neck.

The **superior laryngeal nerve** (n. laryngeus superior) passes obliquely downwards and inwards, behind the external and internal carotid arteries, towards the thyroid cartilage. It divides in its course into two unequal parts—a larger internal and a smaller external laryngeal nerve.

The **internal laryngeal nerve** (ramus internus) passes inwards into the larynx between the middle and inferior constrictor muscles of the pharynx and through the thyro-hyoid membrane. It supplies the mucous membrane of the larynx, reaching upwards to the epiglottis and base of the tongue, and forms communications beneath the ala of the thyroid cartilage with the branches of the inferior laryngeal nerve.

The **external laryngeal nerve** (ramus externus) passes downwards upon the inferior constrictor muscle of the pharynx. It supplies branches to that muscle, and ends in the crico-thyroid muscle.

Communications.—Besides supplying these pharyngeal and laryngeal nerves, the ganglion of the trunk of the pneumogastric has the following communications with other

nerves: (1) with the superior cervical ganglion of the sympathetic; (2) with the hypoglossal; (3) with the loop between the first and second cervical nerves; and (4) with the accessory part of the spinal accessory nerve. This part of the nerve applies itself to the ganglion, and thereby supplies to the vagus nerve the inhibitory fibres for the heart, as well as the motor fibres for the pharynx, œsophagus, stomach and intestines, larynx and respiratory organs.

Branches of the Pneumogastric in the Neck.—In the neck the pneumogastric nerve supplies cardiac branches and (on the right side) the inferior or recurrent laryngeal nerve (Fig. 467).

The **cardiac branches** are **superior** and **inferior.** *On the right side* both cardiac branches pass downwards into the thorax behind the subclavian artery, and proceed alongside the trachea to join the deep cardiac plexus. *On the left side* the two nerves separate on reaching the thorax. The *superior nerve* passes deeply alongside the trachea to join the deep cardiac plexus. The *inferior nerve* accompanies the pneumogastric nerve over the aortic arch, along with the superior cervical cardiac branch of the sympathetic, to end in the superficial cardiac plexus.

The **right inferior laryngeal nerve** arises at the root of the neck, as the pneumogastric nerve crosses over the first part of the subclavian artery. It hooks round the artery, and passes obliquely upwards and inwards behind the subclavian, the common carotid, and the inferior thyroid artery and the thyroid body. It finally disappears beneath the lower border of the inferior constrictor muscle, and ends in supplying the muscles of the larynx. In its course it gives off the following branches:—

(1) **Cardiac branches** arise as the nerve winds round the subclavian artery, and course downwards alongside the trachea to end in the deep cardiac plexus.

(2) **Communicating branches** to the inferior cervical ganglion of the sympathetic arise from the nerve behind the subclavian artery.

(3) **Muscular branches** supply the trachea, œsophagus, and the inferior constrictor of the pharynx.

(4) **Terminal branches** supply the muscles of the larynx (except the crico-thyroid) and communicate beneath the ala of the thyroid cartilage with branches of the internal laryngeal nerve.

Branches of the Vagus in the Thorax.—In the thorax the pneumogastric nerve forms the great pulmonary and œsophageal plexuses. The right nerve, in addition, furnishes cardiac branches; and the left nerve gives off the inferior or recurrent laryngeal nerve.

The **left inferior laryngeal nerve** differs from the nerve of the right side only in its point of origin and in the early part of its course. It springs from the pneumogastric nerve as it crosses the aortic arch, and, after hooking round the arch external to the *ligamentum arteriosum*, it passes upwards in the superior mediastinum in the interval between the trachea and œsophagus to the neck. In the neck its course and relations are similar to those of the nerve of the right side. The branches of the nerve are the same as those of the right nerve. The **cardiac branches** are larger, and, arising below the aortic arch, proceed to the deep cardiac plexus.

Cardiac branches from the right pneumogastric nerve arise in the superior mediastinum, and pass downwards alongside the trachea to join the deep cardiac plexus. On the *right side* thoracic cardiac branches are thus supplied from both the trunk of the nerve and its recurrent branch; *on the left side* the cardiac branches in the thorax arise solely from the recurrent branch.

Abdominal Branches.—After the formation of the œsophageal plexus the two pneumogastric nerves resume their course, and passing along with the gullet through the diaphragm, terminate by supplying the stomach. The *right nerve* enters the abdominal cavity behind the gullet, and is distributed to the posterior surface of the stomach. It sends communicating offsets to the cœliac, splenic, and renal plexuses. The *left nerve* applies itself to the anterior surface and lesser curvature of the stomach, to which it is distributed. It sends communicating offsets along the lesser curvature of the stomach to the right pneumogastric, and between the layers of the small omentum to the hepatic plexus.

The Thoracic Plexuses.

Cardiac Plexuses.—The cardiac branches of the pneumogastric nerve (both cervical and thoracic) combine with the cervical cardiac branches of the sympathetic to form the superficial and deep cardiac plexuses.

The **superficial cardiac plexus** is placed in the hollow of the aortic arch, superficial to the pericardium. It contains a small ganglion (**ganglion of Wrisberg**), and is joined by two small nerves—(1) the cardiac branch from the superior cervical ganglion of the sympathetic, and (2) the inferior cervical cardiac branch of the pneumogastric —both of the left side—which reach it after passing over the arch of the aorta.

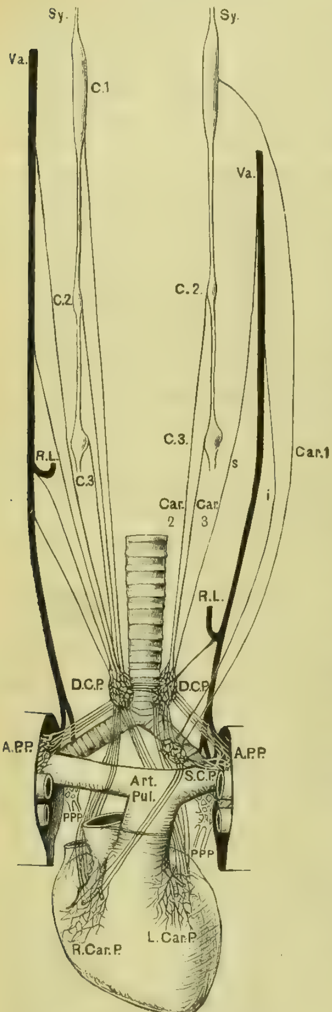


Fig. 468.—The Constitution of the Cardiac Plexuses.

Sy, Cervical sympathetic cord; C.1, Superior, C.2, Middle, and C.3, Inferior cervical ganglia; Car.1, Superior, Car.2, Middle, and Car.3, Inferior cervical cardiac sympathetic branches; Va, Pneumogastric nerve; R.L, Recurrent laryngeal nerve; s, Superior, and i, Inferior cervical cardiac branches of vagus; D.C.P, Deep cardiac plexus; S.C.P, Superficial cardiac plexus; A.P.P, Anterior pulmonary plexus; P.P.P, Posterior pulmonary plexus; R.Car.P, Right, and L.Car.P, Left coronary plexuses; Art.Pul, Pulmonary artery.

Branches and **Communications.**—From the plexus branches of communication pass (1) to the left half of the **deep cardiac plexus**, between the aortic arch and the bifurcation of the pulmonary artery; (2) to the left **anterior pulmonary plexus** along the left branch of the pulmonary artery; (3) the branches of distribution to the heart extend along the pulmonary artery to join the **anterior** or **right coronary plexus**, which supplies the substance of the heart in the course of the right coronary artery.

The **deep cardiac plexus** is much the larger. It is placed behind the arch of the aorta, on the sides of the trachea, just above its bifurcation. It consists of two lateral parts, joined together by numerous communications around the termination of the trachea. The two portions of the plexus are different in their constitution and distribution. The *right half* of the plexus is joined by both the cervical and thoracic branches of the right pneumogastric and by the branches of the right inferior laryngeal nerve, as well as by branches from the superior, middle, and inferior cervical ganglia of the sympathetic. The *left half* of the plexus is joined by the superior cervical cardiac branch of the left pneumogastric, by branches from the left inferior laryngeal nerve, and by branches from the middle and inferior cervical ganglia of the left sympathetic; it also receives a contribution from the superficial cardiac plexus.

The deep cardiac plexus is distributed to the heart and lungs. The *right half* of the plexus for the most part constitutes the **anterior** or **right coronary plexus**, reaching the heart alongside the ascending aorta, and is distributed to the heart substance in the course of the right coronary artery. It is reinforced by fibres from the superficial cardiac plexus, which reach the heart along the pulmonary artery. Fibres from the right half of the deep cardiac plexus pass also to join the **posterior** or **left coronary plexus**, and others extend outwards to join the **anterior pulmonary plexus** of the right side.

The *left half* of the deep cardiac plexus, reinforced by fibres from the superficial cardiac plexus, is distributed to the heart in the form of the **left** or **posterior coronary plexus**, which is joined by a few fibres behind the pulmonary artery from the right half of the plexus, and supplies the heart substance in the course of the left coronary artery. The left half of the plexus

contributes also to the **left anterior pulmonary plexus** by fibres which extend outwards to the root of the lung along the left branch of the pulmonary artery.

Pulmonary Plexuses.—As already stated, the pneumogastric nerve on each side, on reaching the back of the root of the lung, breaks up into numerous plexiform branches for the formation of the posterior pulmonary plexus. From each nerve a few fibres pass to the front of the root of the lung, above its upper border, to form the much smaller anterior pulmonary plexus.

The **anterior pulmonary plexus** on each side is joined by a few fibres from the corresponding part of the deep cardiac plexus, and on the left side from the superficial cardiac plexus as well. It surrounds and supplies the constituents of the root of the lung anteriorly.

The **posterior pulmonary plexus**, placed behind the root of the lung, is formed by the greater part of the pneumogastric nerve, reinforced by fine branches from the second, third, and fourth thoracic ganglia of the sympathetic. Numerous branches proceed from it in a plexiform manner along the bronchi and vessels into the substance of the lung.

Œsophageal Plexus (plexus gulæ).—The œsophagus in the thorax is supplied by the pneumogastric nerve both in the superior and posterior mediastinum. *In the superior mediastinum* it receives branches from the pneumogastric nerve on the right side, and from its recurrent laryngeal branch on the left side.

In the posterior mediastinum it is surrounded by the œsophageal plexus, formed from the trunks of the pneumogastric nerves emerging from the posterior pulmonary plexus, which form a large plexus

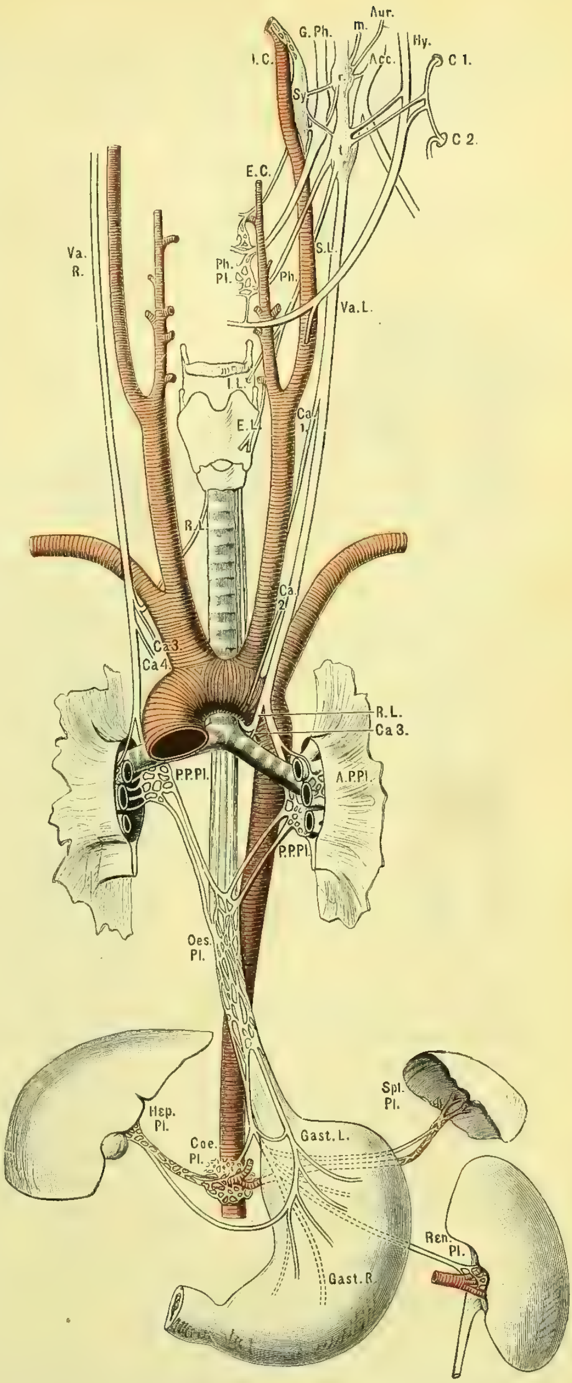


Fig. 469.—The Distribution of the Pneumogastric Nerve.

Va.R, Va.L, Right and left vagi; r, Ganglion of the root and connexions with Sy, Sympathetic, superior cervical ganglion; G.Ph, Glosso-pharyngeal; Acc, Spinal accessory nerve; m, Meningeal branch; Aur, Auricular branch; t, Ganglion of the trunk and connexions with Hy, Hypoglossal nerve; C1, C2, Loop between the first two cervical nerves; Sy, Sympathetic; Acc, Spinal accessory nerve; Ph, Pharyngeal branch; Ph.Pl, Pharyngeal plexus; S.L, Superior laryngeal nerve; I.L, Internal laryngeal branch; E.L, External laryngeal branch; I.C, Internal, and E.C, External carotid arteries; Ca1, Superior cervical cardiac branch; Ca2, Inferior cervical cardiac branch; R.L, Recurrent laryngeal nerve; Ca3, Cardiac branches from recurrent laryngeal nerves; Ca4, Thoracic cardiac branch (right vagus); A.P.Pl, Anterior, and P.P.Pl, Posterior pulmonary plexuses; Oes.Pl, Œsophageal plexus; Gast.R, and Gast.L, Gastric branches of vagus (right and left); Cœ.Pl, Cœliac plexus; Hep.Pl, Hepatic plexus; Spl.Pl, Splenic plexus; Ren.Pl, Renal plexus.

surrounding the gullet. This part of the œsophagus also receives fibres from the great splanchnic nerve and ganglion. From the œsophageal plexus branches supply the muscular wall and mucous membrane of the œsophagus.

Pericardiac branches are also supplied from the plexus to the posterior surface of the pericardium.

The Eleventh or Spinal Accessory Nerve.

The spinal accessory nerve (n. accessorius) consists of two essentially separate parts, different both in origin and in distribution. One portion is **accessory to the vagus nerve**, and arises, in series with the fibres of that nerve, from the side of the medulla oblongata. The other, **spinal portion**, arises from the lateral aspect of the spinal cord, between the ventral and dorsal roots of the spinal nerves, its origin extending from the level of the accessory portion as low as the origin of the sixth cervical nerve (for the deep origin, see p. 477). Successively joining together, the rootlets form a trunk which ascends in the subdural space of the spinal cord, behind the ligamentum denticulatum, to the foramen magnum. There the accessory and spinal portions unite into a single trunk, which leaves the cranial cavity through the jugular foramen in the same compartment of dura mater as the pneumogastric nerve (Fig. 457, p. 636).

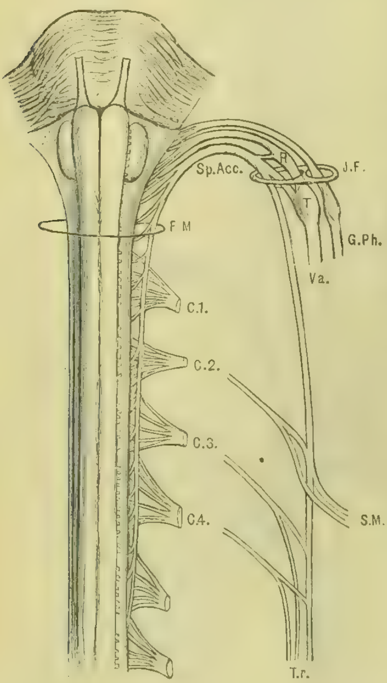


Fig. 470.—Scheme of the Origin, Connexions, and Distribution of the Spinal Accessory Nerve.

Sp.Acc, Spinal accessory nerve ; C.1-4, First four cervical nerves (dorsal roots) ; Va, Pneumogastric nerve ; R, Ganglion of the root ; T, Ganglion of the trunk ; G.Ph, Glosso-pharyngeal nerve ; S.M, Nerves to sterno-cleido-mastoid ; Tr, Nerves to trapezius ; F.M, Foramen magnum ; J.F, Jugular foramen.

In the jugular foramen the **accessory portion of the nerve** (after furnishing a small branch to the ganglion of the root of the pneumogastric nerve) applies itself to the ganglion of the trunk, and in part joins the ganglion, in part the trunk of the nerve beyond the ganglion. By means of these connexions the pneumogastric receives viscero-motor and cardio-inhibitory fibres.

The **spinal portion** of the nerve extends into the neck, where at first it lies along with other nerves, in the interval between the internal carotid artery and the internal jugular vein. Passing obliquely downwards and outwards over the vein, it descends beneath the sterno-mastoid muscle, which it supplies as it pierces it on its deep surface. After crossing the posterior triangle, the nerve ends by supplying the trapezius muscle on its under surface. The spinal portion of the nerve *communicates* in three situations with nerves from the cervical plexus—(1) in or beneath the sterno-mastoid, with the branch for the muscle derived from the second cervical nerve; (2) in the posterior triangle, with branches from the third and fourth cervical nerves; (3) beneath the trapezius, with the branches for the muscle derived from the third and fourth cervical nerves.

The Twelfth or Hypoglossal Nerve.

The hypoglossal nerve (n. hypoglossus) arises by numerous radicles from the front of the medulla oblongata between the pyramid and the olive (Fig. 452, p. 633) (for deep origin, see p. 476). The root fibres arrange themselves in two bundles which separately pierce the dura mater, and unite in the anterior condyloid foramen, or after emerging from the skull. In the neck the nerve arches downwards and forwards towards the hyoid bone, and then turns inwards among the suprahyoid muscles to the tongue. At first it is placed deeply, along with other cranial

nerves, on the outer side of the internal carotid artery; it then curves forwards and downwards over the two carotid arteries lying beneath the digastric and stylo-hyoid muscles. As it crosses the external carotid artery it hooks round the occipital artery. Above the great cornu of the hyoid bone the nerve conceals

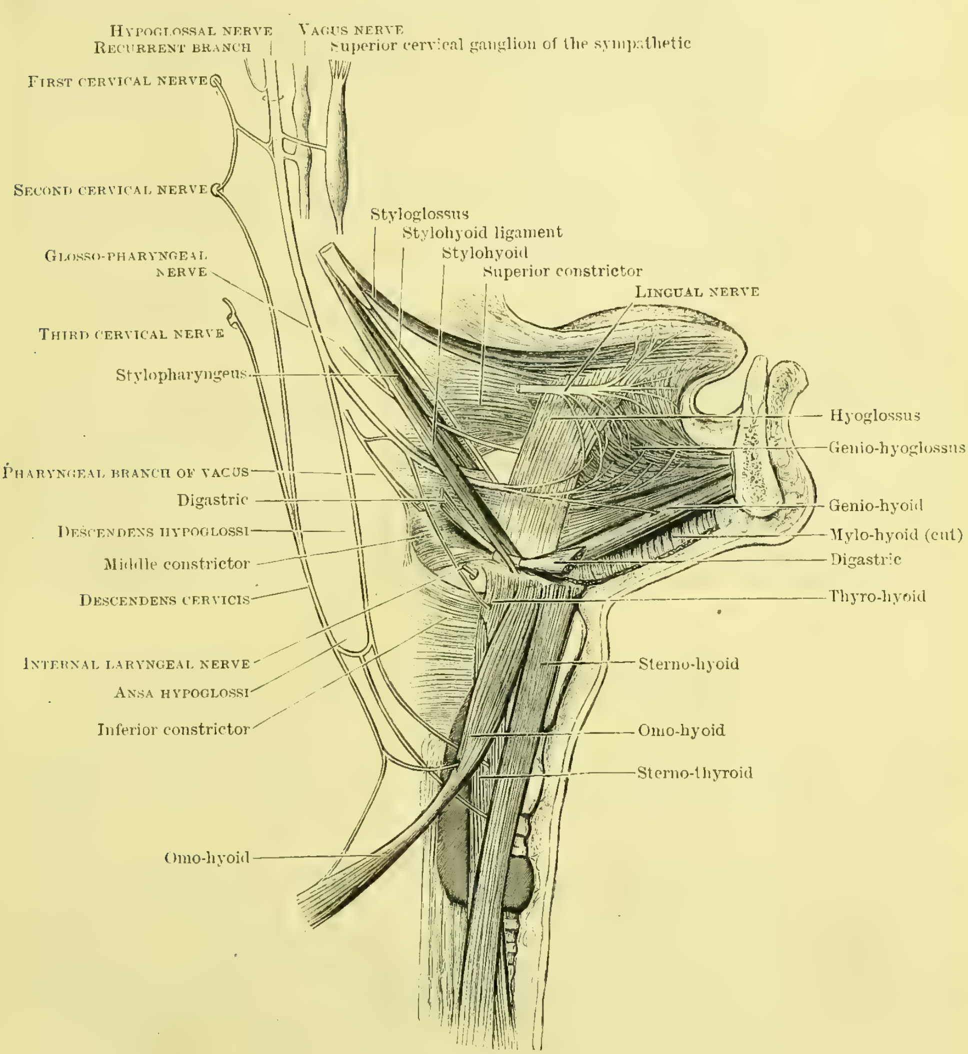


Fig. 471.—The Muscles of the Hyoid Bone and Styloid Process, and the Extrinsic Muscles of the Tongue, with their Nerves.

the lingual artery; and it then disappears between the mylo-hyoid and hyo-glossus muscles to reach the tongue, in the muscular substance of which it terminates.

Communications.—In its course the hypoglossal nerve has the following communications with other nerves:—Near the base of the skull it is connected by small branches with (1) the superior cervical ganglion of the sympathetic; (2) the ganglion of the trunk of the pneumogastric; (3) by a larger branch, with the loop between the first two cervical nerves; (4) as it crosses the external carotid artery it receives a communication from the pharyngeal plexus (*lingual branch of the vagus*); and (5) beneath the mylo-hyoid muscle, at the anterior border of the hyo-glossus, it forms loops of communication with the lingual branch of the inferior maxillary nerve.

The **branches** of the nerve are:—(1) Recurrent; (2) Descending; (3) Thyro-hyoid; and (4) Lingual.

The **recurrent branch** passes from the nerve near its origin to supply the dura

mater of the posterior fossa of the base of the skull. It probably derives its fibres from the communication with the first and second cervical nerves.

The **descending hypoglossal nerve** (n. descendens) is the chief branch given off in the neck. It arises from the hypoglossal nerve as it crosses the internal carotid artery, and descends in the anterior triangle in front of the carotid sheath. It is joined about the middle of the neck by the **descending cervical nerve** (from the second and third cervical nerves). By their union the **hypoglossal loop** (ansa hypoglossi) is formed, from which branches are distributed to the majority of the infrahyoid muscles—both bellies of the omo-hyoid, the sterno-hyoid, and the sterno-thyroid. The descending hypoglossal nerve derives its fibres from the communication to the hypoglossal nerve from the loop between the first and second cervical nerves; so that the ansa hypoglossi is made up of fibres of the first three cervical nerves.

The **nerve to the thyro-hyoid muscle** is a small branch which arises from the hypoglossal nerve before it passes beneath the mylo-hyoid muscle. It descends behind the great cornu of the hyoid bone to reach the muscle. When traced backwards, this nerve is found associated with the loop between the first and second cervical nerves.

The **lingual branches** of the hypoglossal nerve are distributed to the hyo-glossus, genio-hyoid, and genio-hyo-glossus, and to all the intrinsic muscles of the tongue. The nerve to the genio-hyoid is said to be derived from the loop between the first and second cervical nerves. It is not known if these two nerves are implicated in the innervation of the proper muscles of the tongue, but it appears certain that the muscles named—the genio-hyoid, thyro-hyoid, sterno-hyoid, omohyoid, and sterno-thyroid—are not supplied by the hypoglossal, but only by cervical nerves, the genio-hyoid by the first two, the other muscles by the first three cervical nerves.

THE DEVELOPMENT OF THE CRANIAL NERVES.

Omitting the first and second nerves, there is an obvious likeness in the development of the cranial nerves to the formation of the dorsal, afferent or sensory, and the ventral, efferent or motor, roots of the spinal nerves. The **afferent roots** arise from collections of cells which bud off from the alar lamina of the brain, homologous with the dorso-lateral part of the spinal cord. These cells give rise to central and peripheral processes, like the similar processes from the dorsal ganglia of the spinal nerves, producing on the one hand the root fibres connected with the brain, and on the other hand the fibres of the nerve proceeding to the periphery. The **efferent roots**, like the ventral roots of the spinal nerves, arise as the peripheral processes of neuroblasts located in the basal lamina of the primitive brain, which is homologous with the ventro-lateral portion of the spinal cord. The efferent nerves may be separated into two series, according as they arise from the mesial or lateral parts of the basal lamina. The third, fourth, sixth, and twelfth nerves arise from the mesial part of the lamina; the efferent fibres of the fifth, seventh, ninth, tenth, and eleventh nerves arise from the lateral part.

The **olfactory nerve** is associated in its development with the formation of the nasal pit and the olfactory bulb.

The **olfactory nerves** are developed from the epithelium of the nasal pit. These cells furnish neuroblasts—cells with peripheral and central processes, which form a collection of cells—the **olfactory ganglion**. From this ganglion the processes of the neuroblasts extend peripherally and centrally. The peripheral processes produce the so-called **olfactory nerves**, which become connected with the olfactory epithelium. The central processes extend from the olfactory ganglion to the brain, applying themselves to the olfactory bulb, to which they become connected in the second month. The olfactory ganglion becomes incorporated at the same time with the olfactory bulb.

The **optic nerve** is developed wholly from the brain. Its formation begins with the outgrowth of the optic vesicle, a paired hollow outgrowth from the ventral surface of the thalamencephalon. The epiblastic invagination of the lens, growing inwards from the surface, causes the collapse of the vesicle and its conversion into the **optic cup**, the narrow tube connecting the vesicle to the brain becoming the **optic stalk**. This stalk

becomes solid, and forms the basis of the optic tract, optic commissure, and optic nerve. The optic cup, bilaminar in form, and clasping the lens by its margin, is imbedded in mesoblastic tissue, which gives rise to the envelopes of the eyeball, etc. The *outer layer* of the optic cup produces the layer of hexagonal pigment cells of the retina. The cells of the *inner layer* produce the tissue of the retina proper. They form neuroblasts with peripheral and central processes. The peripheral processes are converted into retinal nerve tissues; the central processes extend backwards along the optic stalk, and give rise to the fibrous structure of the optic nerve, optic commissure, and optic tract. Spongioblasts in the inner lamina of the optic cup produce the sustentacular tissue of the retina (Müller's fibres).

The **oculo-motor nerve** arises, like the ventral root of a spinal nerve, from a group of neuroblasts in the mesial part of the basal lamina of the mid-brain. The peripheral fibres extend forwards, to end around the optic cup in the mesoblastic tissue, from which the eye muscles are derived. Numerous cells are carried along with the cell processes in their course, and these have been described as being concerned in the formation of the ciliary ganglion.

The **trochlear nerve** also arises from a group of neuroblasts occupying the mesial part of the basal lamina of the mid-brain, close to its junction with the hind-brain. The peripheral processes do not emerge directly from the brain, but extend dorsally from their origin along the side of the brain to its dorsal aspect, where they appear, after decussating with the fibres of the opposite nerve, just behind the quadrigeminal lamina.

The **trigeminal nerve** is developed by means of a large dorsal and a small ventral root. Their origin is in the main similar to the origin of the roots of a spinal nerve.

The large **dorsal (afferent) root** is formed by means of a cellular bud from the alar lamina of the hind-brain. This bud separates from the brain, and forms the Gasserian ganglion. Its cells becoming bipolar, like the cells of a spinal ganglion, are secondarily connected with the brain by means of their central processes; while the peripheral processes, separating into three groups, proceed along the fronto-nasal and maxillary processes, and along the mandibular arch, to form the three main divisions of the nerve. Numerous cells accompany each main division in its course from the ganglion, and form eventually the subordinate ganglia—the *ciliary* on the ophthalmic nerve, the *spheno-palatine* on the superior maxillary nerve, and the *otic ganglion* on the inferior maxillary nerve.

The small **ventral (efferent) root** of the trigeminal nerve, like the motor ventral root of a spinal nerve, is later in its appearance than the sensory root. It arises as the peripheral fibres of a group of neuroblasts occupying the lateral part of the basal lamina of the hind-brain, which proceed directly to the surface to join the inferior maxillary division of the nerve.

The resemblance between the trigeminal nerve and a typical spinal nerve, though striking, is incomplete. The efferent root does not quite correspond in place of origin with the motor root of a spinal nerve, being lateral and not ventral. The afferent root, while ganglionic and dorsal, differs from the typical segmental spinal nerve in separating into trunks for the supply of more than one segment.

The **abducent nerve** resembles in its mode of development the oculo-motor and trochlear nerves, with which in its origin it is in series. It is formed by the peripheral processes of a group of neuroblasts in the mesial part of the basal lamina in the upper part of the hind-brain. These processes pierce the part of the brain in which, at a later stage, the fibres of the pyramid are developed. They then proceed to the mesoblastic tissue round the optic cup, which is destined to form the eye muscles.

The **facial nerve** has developmentally a double origin. (1) In connexion with the formation of the auditory nerve a group of cells becomes separated from the alar lamina of the hind-brain opposite the auditory vesicle. This group becomes separated into three parts, of which the middle portion is the rudiment of the **geniculate ganglion** (or efferent root). (2) From a group of neuroblasts in the lateral part of the basal lamina of the hind-brain the **efferent root** of the nerve arises in series with efferent fibres of the vago-glossopharyngeal fibres; after a tortuous course within the brain, its fibres emerge beneath the above-mentioned cellular mass, opposite the auditory vesicle. They are joined by the ganglionic root, and winding round the auditory vesicle, become imbedded in the auditory capsule (aqueduct of Fallopius). The chorda tympani nerve appears early as a branch of the facial nerve. It is probable that the pars intermedia, the geniculate ganglion, and the chorda tympani nerve represent the **dorsal afferent element** in the constitution of this nerve.

The **auditory nerve** arises as a cellular bud from the alar lamina of the hind-brain, dorsal to the efferent portion of the facial nerve and opposite to the auditory vesicle.

Becoming separated from the brain, the cellular mass separates into three portions, of which the middle part is associated with the facial nerve and pars intermedia (as the geniculate ganglion), while the mesial and lateral parts are converted into the mesial (vestibular) and lateral (cochlear) ganglia and roots of the auditory nerve. The cells becoming bipolar, their central processes are secondarily connected with the brain on the dorsal (lateral) aspect of the facial nerve; the peripheral processes proceed to the auditory vesicle, to which they are distributed as the vestibular and cochlear nerves. Numerous cells are carried along with the nerve trunks into relation with the auditory capsule, and constitute the vestibular and cochlear ganglia.

The **glosso-pharyngeal** and **pneumogastric nerves** are developed from the side of the hind-brain, both in the same way, and each by two roots. A collection of cells separates itself from the alar lamina of the hind-brain behind the auditory vesicle to form the **ganglionic afferent root.** The ganglion of the pneumogastric is much larger than that of the glosso-pharyngeal. Each ganglion becomes divided into two parts, a proximal and a distal portion, connected together by a commissural band of fibres. The proximal ganglion (jugular ganglion of the glosso-pharyngeal; ganglion of the root of the pneumogastric) is secondarily connected by centripetal fibres to the hind-brain. From the distal ganglion (petrous ganglion of the glosso-pharyngeal; ganglion of the trunk of the pneumogastric) peripheral fibres grow outwards to form the nerve trunk.

Each nerve is also provided with a small **efferent root**, consisting of nerve fibres, arising from a collection of neuroblasts in the lateral part of the basal lamina of the hind-

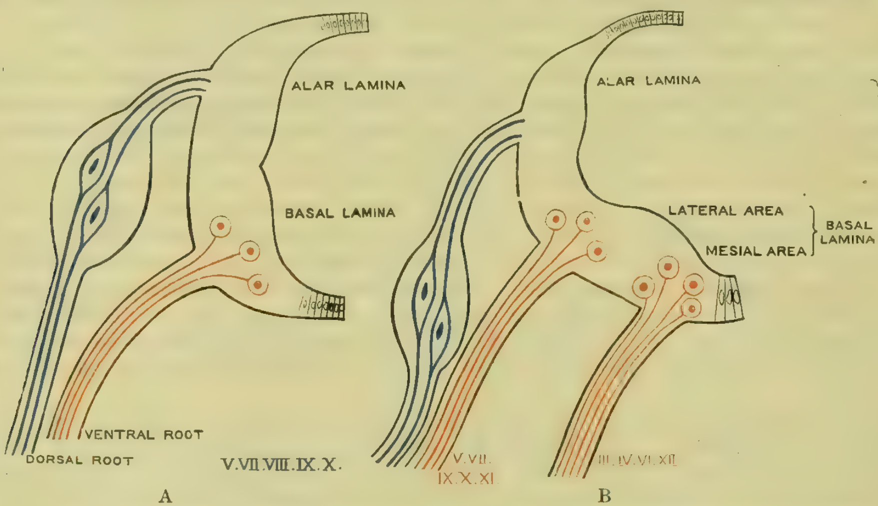


FIG. 472.—COMPARISON OF SPINAL CORD AND HIND-BRAIN; ORIGIN OF NERVE ROOTS (after His).
A. Spinal cord; B. Hind-brain.

brain, and emerging beneath the ganglionic root at the junction of the alar and basal laminæ (in series with the fibres of the efferent root of the facial nerve above and of the spinal accessory nerve below).

The **spinal accessory nerve** arises in two parts—one medullary, the other spinal. The **medullary** (accessory) portion develops as the processes of a series of neuroblasts in the lateral portion of the basal lamina of the hind-brain, which emerge in series with the efferent roots of the glosso-pharyngeal and pneumogastric nerves. The **spinal portion** arises as the processes of a group of neuroblasts in the ventral part of the medullary tube, which at first are directed dorsally in the side of the primitive spinal cord, and, turning outwards, emerge as a series of roots on its lateral aspect.

The **hypoglossal nerve** is developed, not in series with the nerves above-mentioned, but like the third, fourth, and sixth nerves, from the mesial part of the basal lamina of the hind-brain, in the space between the glosso-pharyngeal and nerves above and the first cervical nerve below. It is formed as a series of peripheral processes from a collection of neuroblasts occupying the hind-brain. **Froriep's ganglion** is a transitory collection of nerve-cells developed from the alar lamina of the hind-brain on the dorsal aspect of the nerve, and represents in a rudimentary condition its dorsal ganglionic root. It gives off no branches and soon disappears.

THE MORPHOLOGY OF THE CRANIAL NERVES.

The head and face, possibly the oldest, and from every point of view the most fundamental and important portion of the bodily fabric, present in some respects a more conservative type of structure, and in other aspects have been subject to more profound alterations than other parts of the body. Segmentation is characteristic of the trunk, pervading bones, muscles, vessels, and nerves. An absence of true segmentation is characteristic of the head region—omitting for the moment the cranial nerves. The head is characterised by the possession of an unsegmented tubular nervous system, enclosed in a bony capsule not properly segmented, with which the capsules of the sense-organs become united. The pre-oral and post-oral visceral arches and clefts are not truly segmental like the costal arches of the trunk. The branchial clefts are said to be inter-segmental: and their muscles (associated with the myoblast surrounding the developing heart) are described as visceral, and not myotomic, so that the branchial vessels and nerves (similarly) are not to be regarded as comparable to the segmental vessels and nerves of the trunk. The truly segmental structures present are certain persistent myotomes or muscle plates, which give rise to muscles innervated by the third, fourth, sixth, and twelfth cranial nerves.

Another difficulty in the morphology of the head arises in the absence of body cavity, and the consequent difficulty of differentiating the somatic and splanchnic mesoblast, and the somatic and splanchnic distribution of a given nerve.

Under these circumstances there is little help to be derived from head structures other than the nerves themselves in seeking a solution of the question of the morphological relations of the cranial nerves. The spinal nerves are, generally speaking, all alike. The cranial nerves, on the other hand, are all different. Scarcely any two nerves are alike; and no single cranial nerve possesses in itself all the characteristic features of a spinal nerve. As seen in relation to their development, the cranial nervous system possesses a series of dorsal ganglia, comparable in position and development to the spinal ganglia; and the efferent roots arise in the same way, and occupy somewhat the same position as the ventral roots of the spinal nerves. But there is no single complete segmental nerve in the head. The very essence of the architecture of the head is a want of segmentation; and this character is shared by the cranial nerves. In addition it must be borne in mind that, in relation to the mammalian head, there are organs which have no homologues in the trunk, and on whose existence the arrangement of the cranial nerves depends—*e.g.* sense-organs and gill-arches.

Among the cranial nerves there are several which possess a resemblance to one or other of the elements of a typical spinal nerve. In the neck the origin of the fibres of the spinal accessory nerve is from the side of the spinal cord, and it is in series with the motor roots of the vago-glossopharyngeal, facial, and fifth nerves. His (as shown in the account of the development of the nerves) has described the neuroblastic origin of the motor roots of these nerves from the lateral part of the basal lamina of the primitive brain. They thus form a series apart—lateral motor roots—separable from the series of motor roots originating from the mesial part of the basal lamina, comprising those of the third, fourth, sixth, and twelfth nerves; the latter nerve roots being comparable to and in series with the ventral roots of the spinal nerves. The lateral motor roots are not represented in the spinal series except in the neck. It is questionable if there is any fundamental distinction between the lateral and ventral motor roots of the cranial nerves. The spinal accessory fibres, for example, when traced into the spinal cord, have an origin from the anterior cornu of the cord, and only differ from the motor or ventral root fibres of a spinal nerve in their different course to the surface. The ganglia in association with the cranial nerves are comparable to the spinal ganglia. The fifth nerve, with the Gasserian ganglion, the ganglion of the facial, the ganglia of the auditory, of the glosso-pharyngeal and the vagus, and the transitory (Froriep's) ganglion of the hypoglossal nerves, arise from the brain in a comparable position, and in the same way as the spinal ganglia. But another series of structures —the sense organs of the lateral line, and the so-called "epibranchial" organs, which are highly developed in lower vertebrates (*e.g.* elasmobranchs), and which appear transitorily only, or are absent altogether in mammalian development, may possibly have a share in the formation of certain of these ganglia or parts of them (*e.g.* ciliary ganglion, geniculate ganglion, ganglia of the auditory nerve, petrosal ganglion of the glosso-pharyngeal, and the ganglion of the trunk of the vagus).

Certain of the cranial nerves are apparently distinctly **segmental**, supplying muscles derived from the persisting myotomes of the head. The **first three myotomes** are said to give rise to the muscles of the eyeball. The *first* produces the superior rectus, inferior rectus, internal rectus, and inferior oblique muscles, and its segmental nerve is the **oculo-motor**. The *second myotome* is said to produce the superior oblique muscle, and its segmental nerve is the **trochlear**. The *third myotome* is said to produce the external rectus muscle, and its segmental nerve is the **abducent**. It has been asserted that the tongue muscles are derived from the **last three or four cephalic and first cervical myotomes**, and that the **hypoglossal nerve** is the segmental nerve for these myotomes, comprising the motor elements of several (four or five) segmental nerves. The intervening myotomes between the first three and this occipital series disappearing, the corresponding elements of segmental nerves are supposed to be absent also (Fig. 473).

Certain of the cranial nerves are essentially related to the structures derived from and associated with the pre-oral and post-oral **visceral clefts and arches** (Fig. 474). The **trigeminal nerve** is essentially the nerve of the **mandibular arch**. By its efferent root it supplies the muscles of that arch. By its afferent root and branches it is related to (1) the fronto-nasal process (ophthalmic division and ciliary ganglion); (2) the maxillary arch (superior maxillary nerve); and

(3) the mandibular arch (inferior maxillary nerve). The mandibular is at first the main nerve; and the maxillary division is sometimes regarded as a subordinate branch (præ-branchial, prætrematic) for the supply of the anterior margin of the cleft (mouth), with which the nerve is in relation. The ophthalmic nerve is sometimes regarded as a morphologically separate nerve. The nerves to these arches have been compared to the anterior primary divisions of spinal nerves, the branches which they supply to the forehead and temple (frontal, orbital, and auriculo-temporal) representing the posterior primary divisions. The ganglia on each division of the nerve are formed as extensions from the Gasserian ganglion.

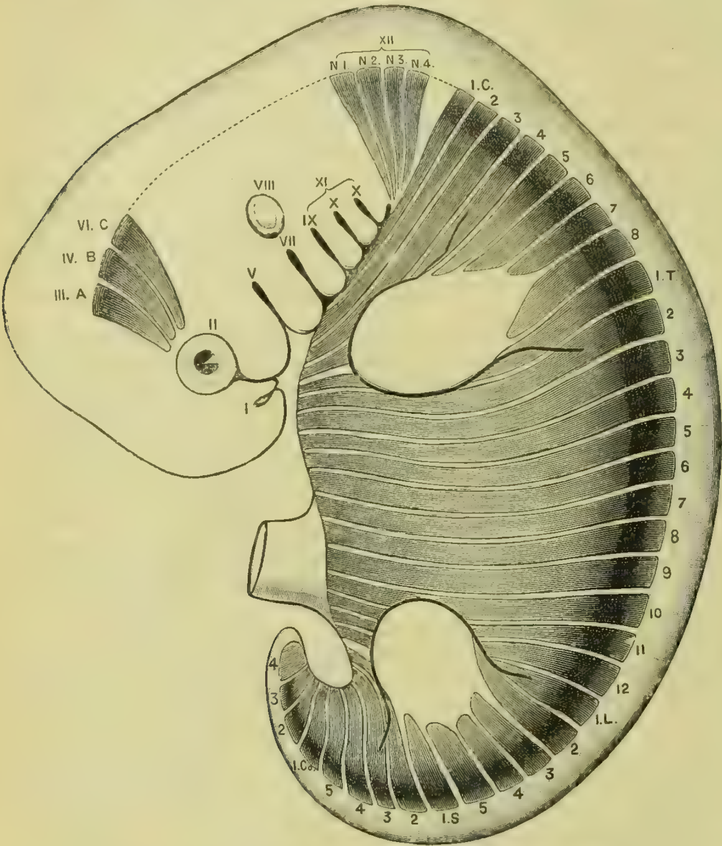


Fig. 473.—Scheme to illustrate the Disposition of the Myotomes in the Embryo in Relation to the Head, Trunk, and Limbs.

A, B, C, First three cephalic myotomes; N, 1, 2, 3, 4, Last persisting cephalic myotomes; C, T, L, S, Co, The myotomes of the cervical, thoracic, lumbar, sacral, and caudal regions; I., II., III., IV., V., VI., VII., VIII., IX., X., XI., XII., refer to the cranial nerves, and the structures with which they may be embryologically associated.

The **facial nerve** is essentially the nerve of the **second (hyoid) arch,** and the cleft in front of that arch (spiracular cleft, Eustachian tube). Its motor root supplies the muscles of that arch (stapedius, stylo-hyoid, and digastric), and the epicranial and facial muscles and platysma myoides, which are developments from the hyoid arch (Rabl). The **chorda tympani nerve** is regarded as the subordinate (præ-branchial, præ-trematic) branch to supply the anterior margin of the first post-oral cleft. It is possible that the geniculate ganglion, with the pars intermedia and the chorda tympani may, in part at least, represent the ganglionic and afferent element of the nerve. Or the geniculate ganglion, and the nerves in relation to it, may be associated with an "epibranchial" sense-organ.

The **auditory nerve,** on the other hand, may be either the sensory element of the branchial nerve, associated with the **hyoid arch** and first post-oral cleft, or it may represent the nerve or nerves belonging to ancestral sense-organs of the lateral line.

The **glosso-pharyngeal** is the branchial nerve of the **third post-oral** (*thyro-hyoid*) **arch** and the cleft in front. Its efferent fibres supply the muscle of this arch,—the stylo-pharyngeus. The superior constrictor of the pharynx is also assigned to this arch; the middle and inferior muscles to the fourth (first branchial) arch. The afferent part of the nerve is possibly composed of two elements; the petrous ganglion being associated with an epibranchial or lateral line sense-organ, and the rest of the nerve forming the afferent fibres for the gill-cleft and arch. The lingual branches are regarded as the main stem (post-trematic), the pharyngeal branches as subordinate branches; the tympanic branch being the præ-branchial or præ-trematic branch for the anterior margin of the gill-cleft.

The **pneumogastric nerve** is generally regarded as representing the fusion of all the branchial nerves behind the glosso-pharyngeal. Its efferent fibres are in series with those of the glosso-pharyngeal above and the spinal accessory nerve below, and belong to the lateral series of His. Its afferent fibres, like those of the glosso-pharyngeal, consist of two elements. The lower ganglion has possible connections with epibranchial sense-organs; the rest of the nerve representing the fused branchial branches of fishes. The **superior laryngeal nerve** is looked upon as the branchial nerve of the **fourth,** and the **inferior laryngeal nerve** as the branchial nerve of the **fifth arch.** The auricular branch is sometimes, but erroneously, regarded as the homologue of one of the lateral nerves of fishes. While the relation of the nerve to the hinder gill

arches and clefts makes it possible to understand the innervation by the vagus of the heart and lungs, no satisfactory explanation is forthcoming of the passage of the nerve into the abdomen, and its distribution to the stomach and other organs below the diaphragm.

The **spinal accessory nerve** consists of two parts. The *accessory portion* of the nerve consists of efferent fibres for the **branchial region,** in series with the lateral motor roots of the glosso-pharyngeal and vagus nerves. The *spinal portion* of the nerve is also composed of efferent fibres, and represents the only lateral motor elements in relation to the spinal cord.

Olfactory Nerve. — There is absolute uncertainty regarding the morphology of this nerve. It consists of three existing elements—(1) the **olfactory bulb,** derived from the cerebral hemisphere, solid in man, but a hollow cerebral diverticulum in certain animals, and forming the rhinencephalon; (2) the **olfactory ganglion,** with its central and peripheral processes, derived from the ectoderm; (3) the **nasal pit.** Attention has been specially fixed on the olfactory ganglion, which has been compared to (1) a dorsal spinal ganglion, derived from the anterior end of the medullary groove; and to (2) a lateral line sense-organ.

The **optic nerve** also presents an insoluble problem in regard to its morphological position in the series of cranial nerves. The optic stalk and optic cup have been regarded as a highly-modified dorsal ganglion; but there is insuperable difficulty in accepting this view. The peripheral processes do not become connected with either ectodermal or mesoblastic structures, but become the tissue of the retina; while the central processes, growing backwards, envelop the optic stalk, and obtain connexions with the brain. The retina must be regarded as a highly-modified layer, morphologically in series with the wall of the fore-brain; and the ectodermal structure of superficial origin comparable to the olfactory ganglion or the auditory vesicle is the lens (which may possibly be homologous with a lateral line sense-organ). The optic nerve, optic commissure, and optic tract are then to be looked upon as cerebral commissures, and not nerves in the ordinary sense.

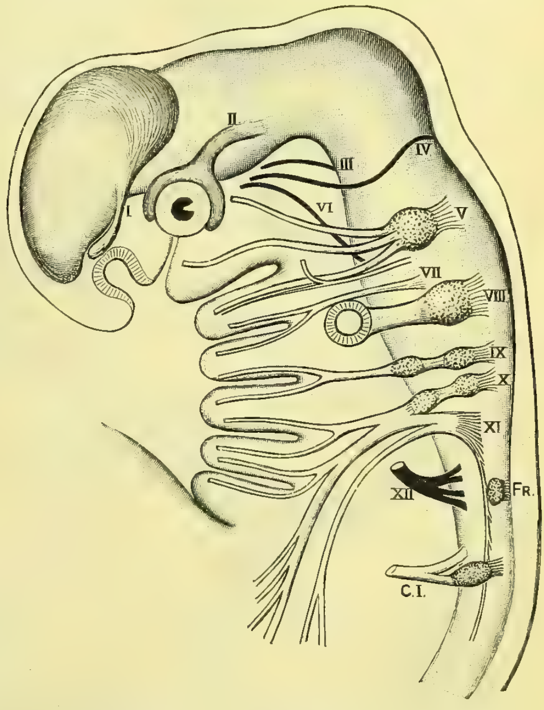


FIG. 474.—SCHEME TO ILLUSTRATE THE EMBRYOLOGICAL ARRANGEMENT OF THE CRANIAL NERVES.

I. to XII. Cranial nerves; FR, Froriep's ganglion; C.I, Roots and trunk of the first cervical nerve.

The simplest and most primitive condition of the head, in relation to the morphology of the cranial nerves, is found before the formation of the gill-clefts, when the salient features are a tubular and simple brain, and a series of superficial invaginations which pass from the surface inwards to become connected with outgrowths corresponding to them from the primitive brain. On either side of the head three hollow invaginations occur. (1) The **nasal pit** bearing the olfactory epithelium becomes connected by the olfactory ganglion with the rhinencephalon, an outgrowth from the fore-brain, and so forms the basis of an olfactory organ and nerve; (2) a similar invagination produces the **lens,** connected with a protrusion of the optic vesicle from the fore-brain, by which the basis of the eye and the optic nerve is formed; (3) behind the buccal cavity a third invagination forms the **auditory vesicle,** which is connected with the solid extension from the hind-brain of the acoustic ganglia, to form the essentials of the organ of hearing and the auditory nerve.

The trigeminal nerve is essentially the nerve of the buccal cavity, and the subordinate cavities, nasal and oral, derived from it. The **branchial arches and clefts** are secondary structures, and their nerves are (1) the trigeminal for the first (mandibular) arch and the cleft in front of it; (2) the facial for the second (hyoid) arch and cleft; (3) the glosso-pharyngeal for the third (thyro-hyoid) arch and cleft; and (4) the pneumogastric for the succeeding arches and clefts. The bulbar part of the spinal accessory nerve is inseparable from the motor portion of the vago-glosso-pharyngeal nerves; the spinal part is beyond the series of the cranial nerves.

Lastly, there are certain truly **segmental nerve elements,** motor fibres which, remaining associated with certain persistent cephalic myotomes, give rise to the oculo-motor, trochlear, abducent, and hypoglossal nerves.

THE SYMPATHETIC NERVOUS SYSTEM.

The sympathetic nervous system consists of a pair of elongated gangliated cords (nervi sympathici), extending from the base of the skull to the coccyx; connected, on the one hand, by a series of branches to the spinal nervous system, and on the other hand giving off an irregular series of branches to the viscera. At its cephalic end each sympathetic cord is continued in a plexiform manner into the cranial cavity along with the internal carotid artery, and forms complex relationships with certain cranial nerves. At their caudal ends the two sympathetic cords become joined together by fine filaments, and are connected by the coccygeal ganglion (g. impar).

The sympathetic system (1) serves to rearrange and distribute fibres derived from the cerebro-spinal system to the viscera and vessels of the splanchnic area; (2) it transmits to the cerebro-spinal system afferent fibres from the viscera; and (3) it transmits fibres to the vessels, involuntary muscles and glands, in the course of the somatic divisions of the spinal nerves.

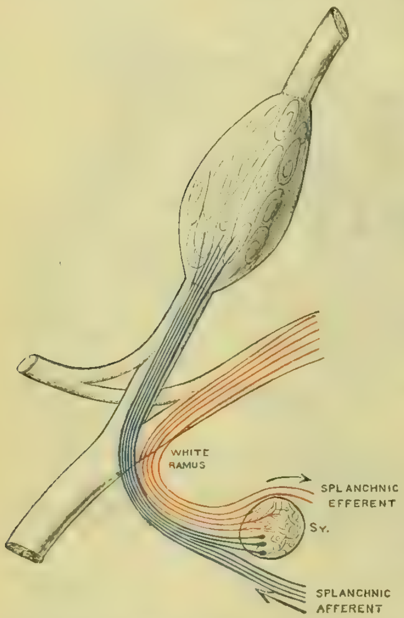


FIG. 475.—SCHEME OF THE CONSTITUTION OF THE WHITE RAMUS COMMUNICANS OF THE SYMPATHETIC.

The roots and trunks of a spinal nerve are shown, with the white ramus passing between the spinal nerve and a sympathetic ganglion (Sy). The splanchnic efferent fibres (in red) are shown, partly ending in the ganglion, and partly passing beyond the ganglion into a peripheral branch. The splanchnic afferent fibres (in blue) are shown, partly entering the ganglion, and passing upwards or downwards in the gangliated cord; partly passing over the cord into peripheral branches.

General Structure of the Sympathetic System.—The sympathetic system is composed of two elements—ganglia and nerve fibres.

The **ganglia** (g. trunci sympathici) are variable in number, form, size, and position. They are not definitely segmental in position, but they are always connected together by a system of narrow commissural cords of nerve fibres. A ganglion consists of a larger or smaller number of multipolar nerve-cells, enclosed in a capsule of connective tissue. Each cell is provided with one *axon* and a number of *dendrites.* The axon may enter into the composition of (*a*) the commissural cord; (*b*) a central branch (gray ramus communicans); or (*c*) a peripheral branch from the sympathetic cord. These axons are commonly medullated at their origin, but become non-medullated in their course from the parent cell. Besides these ganglia, two other series of ganglia are present in connexion with the peripheral branches of the sympathetic,—intermediate or **collateral ganglia,** on the branches or in the sympathetic plexuses, and **terminal ganglia,** in close relation to the endings of the nerves in the viscera.

The **nerve fibres** in the sympathetic system are of two classes, medullated and non-medullated. The distinction is not absolute. The medullated fibres may lose their medullary sheaths before reaching their terminations; and the non-medullated fibres may at their origin possess a medullary sheath. The **medullated fibres** form the series of *white rami communicantes* (the visceral branches of the spinal nerves). They take origin from the anterior primary divisions of certain spinal nerves in two streams, **thoracico-lumbar** from the first (or second) thoracic to the second or third lumbar nerve, and **pelvic,** or **sacral,** from the third, and second or fourth sacral nerves. The roots of these nerves arise from both dorsal and ventral roots of the spinal nerves, but in largest numbers from the ventral root. The **fibres from the ventral root** are of very small size. They are the axons of nerve-cells within the spinal cord, and passing through the white ramus, they enter the sympathetic cord, and end by forming arborisations around

the cells of a sympathetic ganglion. There are three known courses for such a fibre to take in relation to the sympathetic system—(*a*) *It may end in the ganglion* with which it is immediately related; (*b*) *it may course upwards or downwards* in the commissural cord to reach a neighbouring ganglion; (*c*) *it may pass beyond the gangliated cord* to end in relation to cells of the peripheral (collateral) ganglia along with fibres of distribution from the sympathetic ganglia. These fibres are **splanchnic efferent fibres**; motor for the unstriped muscular tissue of the vessels and viscera, and secretory for the glands in the splanchnic area. The **fibres from the dorsal root** of the spinal nerve entering into the composition of the *white ramus communicans* are the axons of spinal ganglion cells. They constitute the **splanchnic afferent fibres,** and probably traverse the sympathetic gangliated cord, passing upwards, downwards, and outwards, without being connected with its cells. They are the sensory fibres for the viscera, which they reach along with the peripheral branches arising from the sympathetic cord itself. It is not certain that fibres from the dorsal ganglia are only found in connexion with nerves provided with distinct white rami. Similar medullated fibres are found also in the gray rami communicantes.

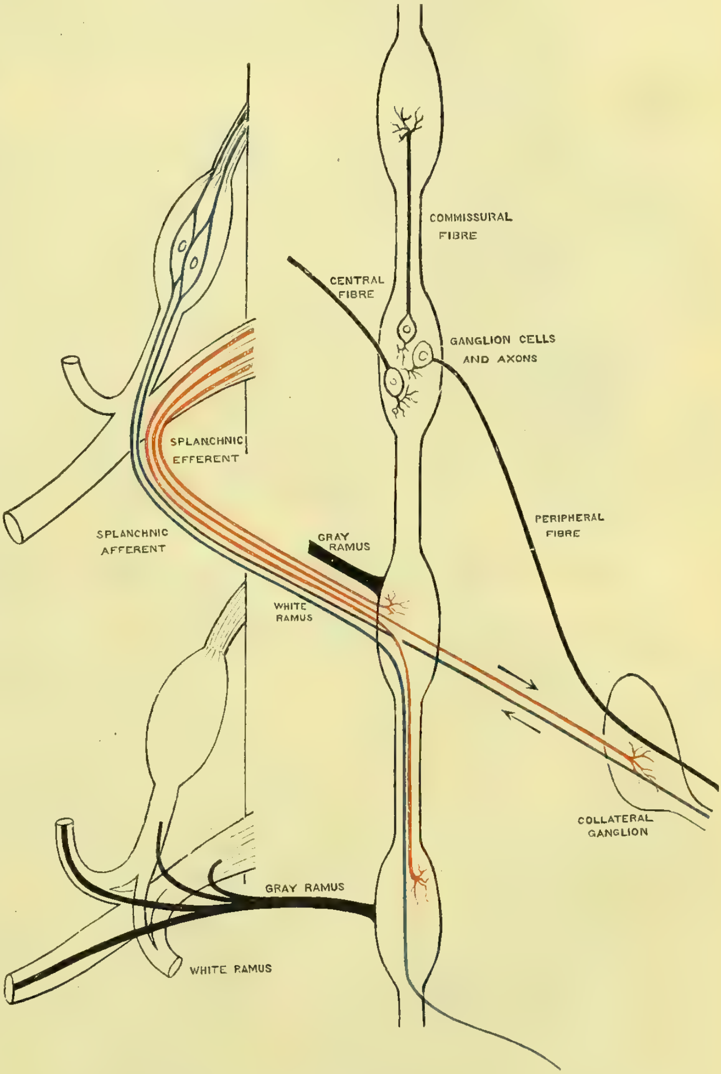


FIG. 476.—SCHEME OF THE CONSTITUTION AND CONNEXIONS OF THE GANGLIATED CORD OF THE SYMPATHETIC.

The gangliated cord is indicated on the right, with the arrangement of the fibres arising from the ganglion cells. On the left the roots and trunks of spinal nerves are shown, with the arrangement of the white ramus communicans above and of the gray ramus below.

The **non-medullated fibres** in the sympathetic system are derived from the axons of the sympathetic ganglion cells. They have different destinations. (*a*) Some fibres appear to contribute to the *formation of the commissural cord* connecting the ganglia together, and to end in aborisations round the cells of a neighbouring ganglion. (*b*) Non-medullated fibres form a large part of the system of *peripheral* (*splanchnic efferent*) *branches,* streaming into the splanchnic area in an irregular manner, both from the ganglia and the connecting commissures. (*c*) The *gray rami communicantes* form a series of non-medullated fibres (with a small number of medullated fibres intermingled) proceeding *centrally from the ganglia to*

the spinal nerves. These gray rami are found in connexion with each and all of the spinal nerves. Their origin from the gangliated cord is irregular: they may come from the ganglia or the commissure; they may divide after their origin, so that two spinal nerves are supplied from one ganglion; or two ganglia may supply branches to a single spinal nerve. In relation to the spinal nerve, the gray ramus is distributed along the somatic divisions of the nerve, supplying branches to the unstriped muscular fibres (vaso-motor, pilo-motor) and glands (secretory). They also provide small recurrent branches, ending in the membranes enveloping the spinal nerve-roots. Mingled with the non-medullated fibres of the gray rami are found a small number of medullated fibres, regarded as medullated sympathetic fibres, and axons from the dorsal spinal ganglia incorporated with this ramus.

The **commissural cords** of the sympathetic system are composed of white and gray fibres. The **white fibres** are: (1) Splanchnic efferent fibres, passing to a ganglion above or below the point of entrance into the sympathetic system; (2) splanchnic afferent fibres, guided along the commissure and over or through the ganglia. The **gray fibres** are the axons of sympathetic ganglion cells: (1) true commissural fibres passing into connexion with the cells of a neighbouring ganglion; (2) fibres passing along the commissure for a certain distance upwards or downwards before entering the splanchnic area as peripheral branches.

The **peripheral (splanchnic) branches** from the sympathetic cord consist of—(1) white fibres—splanchnic afferent fibres unconnected with cells, and splanchnic efferent fibres which, after passing over the gangliated cord, are on their way to join peripheral (collateral) or terminal ganglia in relation to the viscera; and of (2) gray fibres, splanchnic efferent branches, the axons of sympathetic ganglion cells distributed to the vessels and viscera in the splanchnic area.

THE CERVICAL PART OF THE SYMPATHETIC CORD.

The cervical part of the sympathetic cord may be regarded as an upward prolongation of the primitive sympathetic system along the great vessels of the neck. It is characterised by the absence of **white rami communicantes** connecting it with the cervical spinal nerves. Its spinal fibres ascend from the upper thoracic nerves in the commissural cord, and are connected with the cells of the cervical ganglia. The branches from the ganglia in the neck are distributed to structures in the head, neck, and thorax: (1) motor fibres to involuntary muscles (*e.g.* dilator of the pupil); (2) vaso-motor fibres along the arteries of the head and neck and upper limbs; (3) pilo-motor fibres along the cervical spinal nerves to the skin of the head and neck; (4) cardio-motor fibres; (5) and secretory fibres (for the submaxillary gland).

The gangliated cord in the neck is placed upon the prevertebral muscles behind the carotid arteries. It extends from the root of the neck, where it is continuous behind the subclavian artery with the thoracic portion of the cord, to the base of the skull, where it ends in the formation of plexiform branches upon the internal carotid artery. It consists of a narrow commissural cord composed of medullated and non-medullated fibres, on which are two or three ganglia—a superior ganglion at the upper end, an inferior ganglion at the point of junction with the thoracic portion of the cord, and an intermediate middle ganglion varying in position and not always present.

The **superior cervical ganglion** (g. cervicale superius) is placed near the base of the skull, between the internal jugular vein and the internal carotid artery. Irregular in shape, it is the largest of the sympathetic ganglia, measuring three-quarters of an inch or more in length. The commissural cord connects it with the **middle ganglion** (g. cervicale medium), which is of small size, is frequently absent, and may be divided into two parts. It is usually placed over the inferior thyroid artery as it crosses behind the carotid sheath.

The **inferior ganglion** (g. cervicale inferius) is joined by the commissural cord to the middle (or superior) ganglion above, and is imperfectly constricted off from the first thoracic ganglion below. It is of considerable size, irregular in shape, and is

placed behind the first part of the subclavian artery in the interval between the last cervical transverse process and the neck of the first rib.

The **branches** from the cervical sympathetic ganglia and cord are divisible into two sets—(*A*) Central communicating branches for other nerves; (*B*) peripheral branches of distribution, which alone, or along with other nerves, form plexuses, accompanying and supplying vessels and viscera of the head, neck, and thorax. Although this distinction is made, it is to be borne in mind that the branches of communication are as much nerves of distribution as the others.

Superior Cervical Ganglion.

Central Communicating Branches.—1. **Gray rami communicantes** pass from the ganglion to the anterior primary divisions of the first four cervical nerves.

2. **Communications with Cranial Nerves.**—Just outside the skull, in the deep part of the neck, communicating branches pass to the following cranial nerves: (*a*) to the petrous ganglion of the glosso-pharyngeal and the ganglion of the root of the pneumogastric (n. jugularis); (*b*) to the ganglion of the trunk of the pneumogastric; (*c*) to the hypoglossal nerve.

Peripheral Branches of Distribution.—1. **Pharynx.**—A **pharyngeal branch** courses downwards and inwards behind the carotid sheath to reach the wall of the pharynx, where it joins (along with the pharyngeal branches of the glosso-pharyngeal and pneumogastric nerves) in the formation of the **pharyngeal plexus**, supplying the muscles and mucous membrane of the pharynx.

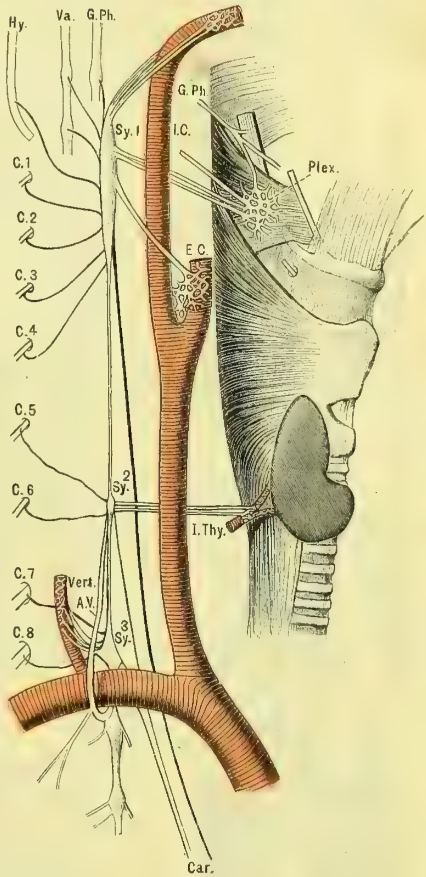


Fig. 477.—The Distribution of the Sympathetic Gangliated Cord in the Neck.

Sy.1, Superior cervical ganglion, and connexions and branches; I.C, Internal carotid artery; G.Ph, Glosso-pharyngeal; Va, Vagus; Hy, Hypoglossal; C.1, 2, 3, 4, First four cervical nerves; Plex, Pharyngeal plexus; G.Ph, Glosso-pharyngeal nerve; E.C, To external carotid artery; Sy.2, Middle cervical ganglion, connexions and branches; C.5, 6, Fifth and sixth cervical nerves; I.Thy, Inferior thyroid artery; A.V, Ansa Vieussenii; Sy.3, Inferior cervical ganglion, connexions and branches; C.7, 8, Seventh and eighth cervical nerves; Vert, Vertebral plexus; Car, Cardiac branches.

2. **Heart.**—The **superior cervical cardiac** branch is a slender nerve which, on the *right side*, descends behind the large vessels into the thorax to join the deep cardiac plexus. On the *left side* the course of the nerve is similar in the neck, but in the superior mediastinum it passes between the left carotid and subclavian arteries, and over the aortic arch, to join with the inferior cervical cardiac branch of the pneumogastric in the formation of the superficial cardiac plexus. In their course both nerves form connexions with the other cervical cardiac nerves of the sympathetic, and with cardiac and other branches of the pneumogastric (external and inferior laryngeal).

3. **Vessels.**—(*a*) The **external carotid branch** passes forwards to the external carotid artery, and forms the **external carotid plexus**, which supplies offsets to that artery and its branches, as well as to the inter-carotid body. From the subordinate plexuses on the facial and middle meningeal arteries sympathetic fibres are supplied to the submaxillary and otic ganglia respectively.

(*b*) The **internal carotid branch** is the attenuated upward prolongation of the ganglion, which applies itself to the internal carotid artery as it enters the temporal bone. This branch subdivides into outer and inner parts, which form plexuses

investing the artery in the cranium. The outer division forms the lower **carotid plexus** (pl. caroticus internus); the inner division gives rise to the upper **cavernous plexus** (pl. cavernosus). Both plexuses supply offsets to the artery and its branches, and form communications with certain cranial nerves.

The **carotid plexus** communicates by fine branches with (*a*) the abducent nerve, and (*b*) the Gasserian ganglion, and gives off (*c*) the great deep petrosal and (*d*) the small deep petrosal nerves. The **great deep petrosal nerve** joins the great superficial petrosal nerve from the geniculate ganglion of the facial, upon the foramen lacerum medium. By their union the **Vidian nerve** is formed, which, after traversing the Vidian canal, ends in Meckel's ganglion. The **small deep petrosal nerve** passes to the **tympanic plexus.** This plexus, formed by the small deep petrosal nerve, the tympanic branch of the glosso-pharyngeal, and a twig from the geniculate ganglion of the facial nerve, is placed on the inner wall of the tympanum. It supplies the mucous lining of the tympanum and Eustachian tube; and the small superficial petrosal nerve passes from it to the otic ganglion.

The **cavernous plexus** communicates with (*a*) the oculo-motor, and (*b*) the trochlear nerves, and (*c*) the ophthalmic division of the trigeminal nerve; it also (*d*) supplies twigs to the pituitary body, and (*e*) forms the sympathetic root of the ciliary ganglion. This may pass to the ganglion independently, or may be incorporated in the long root of the ganglion from the nasal branch of the ophthalmic nerve.

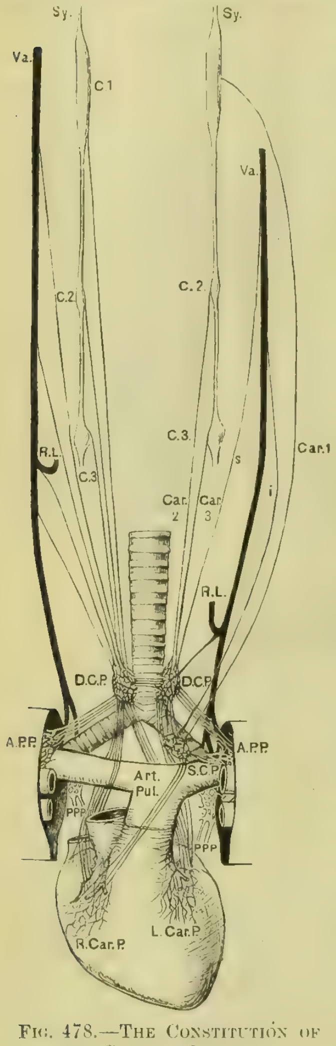


FIG. 478.—THE CONSTITUTION OF THE CARDIAC PLEXUSES.

Sy, Cervical sympathetic cord; C.1, Superior, C.2, Middle, and C.3, Inferior cervical ganglia; Car.1, Superior, Car.2, Middle, and Car.3, Inferior cervical cardiac sympathetic branches; Va, Pneumogastric nerve; R.L, Recurrent laryngeal nerve; s, Superior, and i, Inferior cervical cardiac branches of vagus; D.C.P, Deep cardiac plexus; S.C.P, Superficial cardiac plexus; A.P.P, Anterior pulmonary plexus; P.P.P, Posterior pulmonary plexus; R.Car.P, Right, and L.Car.P, Left coronary plexuses; Art.Pul, Pulmonary artery.

MIDDLE CERVICAL GANGLION.

Central Communicating Branches. — 1. **Gray rami communicantes** arise from the ganglion for the anterior primary divisions of the fifth and sixth cervical nerves. 2. The subclavian loop (**ansa Vieussenii**) is a loop of communication from this ganglion, which, after passing over and supplying offsets to the subclavian artery and its branches, joins the inferior cervical ganglion.

Peripheral Branches of Distribution.—1. **Heart.** —A slender **middle cervical cardiac branch** descends, either separately or in company with other cardiac nerves, behind the large vessels into the thorax, where it ends in the deep part of the cardiac plexus on each side.

2. **Thyroid Body.** — Branches extend inwards along the inferior thyroid artery to supply the thyroid body.

When the middle ganglion is absent, the branches described arise from the commissural cord.

INFERIOR CERVICAL GANGLION.

Central Communicating Branches. — 1. **Gray rami communicantes** arise from this ganglion for the anterior primary divisions of the seventh and eighth cervical nerves. 2. The **subclavian loop** already mentioned connects the middle and inferior ganglia over the front of the subclavian artery. 3. A communication frequently occurs with the inferior laryngeal nerve.

Peripheral Branches of Distribution.—1. **Heart.**—An **inferior cervical cardiac branch** is given off on each side to enter the deep cardiac plexus.

2. **Vessels.**—(*a*) The **vertebral plexus** is a dense plexus of fibres surrounding and supplying the vertebral artery and its branches in the neck and the cranial cavity. (*b*) The **subclavian plexus** is derived from the subclavian loop, and supplies small offsets to the subclavian artery. It gives branches to the internal mammary artery, and communicates with the phrenic nerve.

THE THORACIC PART OF THE SYMPATHETIC CORD.

The thoracic part of the sympathetic cord consists of a variable number of ganglia of an irregularly angular or fusiform shape, joined together by commissural cords of considerable thickness. The number of ganglia is usually ten or eleven; but the first and sometimes others may be so fused with the neighbouring ganglia as to still further reduce the number. This part of the sympathetic cord is characterised by its union with the thoracic spinal nerves. Each thoracic nerve, with the possible exception of the first, sends a **visceral branch** (white ramus communicans) to join the gangliated cord in the thorax. These white rami separate into two main streams in relation to the sympathetic cord. Those of the *upper five* nerves are for the most part directed upwards in the gangliated cord to be distributed through the cervical part of the sympathetic in the manner already described. The white rami of the *lower thoracic* nerves are for the most part directed downwards in the lower part of the sympathetic cord and its branches, to be distributed in the abdomen; at the same time some of their fibres are directly associated with the supply of certain thoracic viscera,—lungs, aorta, œsophagus.

These white rami are composed of (1) **splanchnic afferent fibres** passing from its peripheral branches through the sympathetic cord into the dorsal ganglia of the spinal nerves—medullated nerve-fibres unconnected with sympathetic ganglion cells; and (2) **somatic and splanchnic efferent fibres**, small medullated nerves, which, after a longer or shorter course

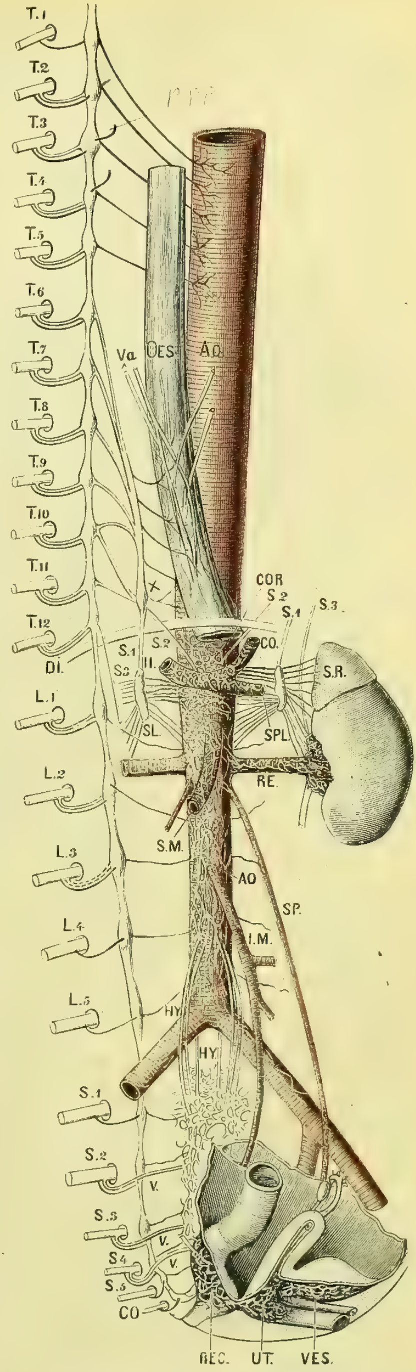


FIG. 479. — THE ARRANGEMENT OF THE SYMPATHETIC SYSTEM IN THE THORAX, ABDOMEN, AND PELVIS.

T.1-12; L.1-5; S.1-5; Co, Anterior primary divisions of spinal nerves, connected to the gangliated cord of the sympathetic by rami communicantes, white (double lines) and gray (single lines); OES, Œsophagus and œsophageal plexus; AO, Aorta and aorta plexus; Va, Vagus nerve joining œsophageal plexus; S.1, Great splanchnic nerve; X, Great splanchnic ganglion; S.2, Small splanchnic nerve; S.3, Least splanchnic nerve; Co, Coronary artery and plexus; SPL, Splenic artery and plexus; H, Hepatic artery and plexus; SL, Semilunar ganglion; Di, Diaphragm; S.R, Supra-renal capsule; RE, Renal artery and plexus; S.M, Superior mesenteric artery and plexus; SP, Spermatic artery and plexus; I.M, Inferior mesenteric artery and plexus; HY, Hypogastric nerves and plexus; REC, Rectal plexus; UT, Uterine plexus; VES, Vesical plexus; V.V.V, Visceral branches from sacral nerves.

in the gangliated cord or its peripheral branches, become connected with the sympathetic ganglion cells, or with the cells of peripheral (collateral or terminal) ganglia, from which again (non-medullated) axons proceed to supply branches to viscera and vessels. The ultimate destination of the upper stream of white rami from the thoracic nerves has been mentioned in the description of the cervical sympathetic ; the peripheral branches supplying thoracic organs contain vaso-motor fibres for the lungs and aorta. The peripheral branches from the lower part of the sympathetic cord in the thorax, receiving white rami from the lower thoracic nerves, are mainly destined for distribution to structures below the diaphragm. They comprise (*a*) viscero-inhibitory fibres for the stomach and intestines; (*b*) motor fibres for part of the rectum ; (*c*) pilo-motor fibres for the lower part of the body; (*d*) vaso-motor fibres for the abdominal aorta and its branches, and for the lower limbs; (*e*) secretory, and (*f*) sensory fibres for the abdominal viscera. The thoracic part of the sympathetic cord is placed upon the heads of the ribs, and is covered over by the pleura.

The **branches** from the gangliated cord are, as in the neck, divisible into two sets—(*A*) Central branches, communicating with other nerves, and (*B*) peripheral branches, distributed in a plexiform manner to the thoracic and abdominal viscera.

Central Communicating Branches. — The **white rami communicantes** from the thoracic nerves have already been described. Passing forwards from the beginning of the anterior primary divisions of the nerves, they become connected with the ganglia or the commissural cord of the sympathetic.

The **gray rami communicantes** are branches arising irregularly from each thoracic ganglion, which, passing backwards along with the white rami, join the anterior primary divisions of the thoracic nerves.

Peripheral Branches of Distribution.—These branches arise irregularly from the ganglia and the commissural cord. They are composed of non-medullated fibres (splanchnic efferent), derived from the ganglion cells, and medullated fibres (splanchnic efferent and afferent), derived directly from the white rami, without the intervention of the cells of the ganglia.

1. **Pulmonary Branches.**—From the gangliated cord opposite the second, third, and fourth ganglia fine filaments arise which join the posterior pulmonary plexus.

2. **Aortic Branches.**—The upper part of the thoracic aorta receives fine branches from the upper five thoracic ganglia.

3. **Splanchnic Nerves.**—Three nerves arise from the lower part of the gangliated cord, partly from the ganglia themselves, and partly from the commissural cord between the ganglia. Passing downwards over the bodies of the thoracic vertebræ they pierce the diaphragm, to end in the abdomen.

(*a*) The **great splanchnic nerve** (n. splanchnicus major) arises from the gangliated cord between the fifth and ninth ganglia. By the union of several irregular strands a nerve of considerable size is formed, which descends in the posterior mediastinum, and piercing the crus of the diaphragm, joins at once the upper end of the *semilunar ganglion* of the solar plexus. In its course in the thorax the **great splanchnic ganglion** (g. splanchnicum) is found upon the nerve. It is more prominent in the fœtus than in the adult. From both nerve and ganglion branches arise in the thorax for the supply of the œsophagus and descending thoracic aorta (Fig. 479).

(*b*) The **small splanchnic nerve** (n. splanchnicus minor) arises from the gangliated cord opposite to the ninth and tenth ganglia. It passes over the bodies of the lower thoracic vertebræ, pierces the diaphragm near or along with the great splanchnic nerve, and ends in the **solar plexus** (*aortico-renal ganglion*).

(*c*) The **least splanchnic nerve** (n. splanchnicus imus) arises from the last thoracic ganglion of the sympathetic, or it may be a branch of the smaller splanchnic nerve. It pierces the diaphragm, and ends in the *renal plexus*.

THE LUMBAR PART OF THE SYMPATHETIC CORD.

The lumbar part of the sympathetic cord is placed upon the bodies of the lumbar vertebræ, internal to the origins of the psoas muscle, and in front

of the lumbar vessels. It is connected with the thoracic portion of the cord by an attenuated commissural cord, which either pierces or passes behind the diaphragm. It is continuous below with the sacral portion of the cord by a commissure, which passes behind the common iliac artery. It is joined by medullated fibres (white rami communicantes) from the first two lumbar spinal nerves, and it contains as well medullated fibres continued down from the lower part of the thoracic gangliated cord, and derived from the visceral branches (white rami communicantes) of the lower thoracic nerves. This part of the gangliated cord is characterised by great irregularity in the number of the ganglia. They are usually four in number, but there are frequently more (up to eight); and in extreme cases fusion may occur to such an extent that the separation of individual ganglia becomes impossible.

White rami communicantes.—The first two (or three) lumbar spinal nerves possess visceral branches which form white rami communicantes joining the upper lumbar ganglia or the gangliated cord. These nerves form the lower limit of the thoracic-lumbar visceral branches of the spinal nerves. They comprise vaso-motor fibres (for the genital organs), and motor fibres for the bladder and uterus.

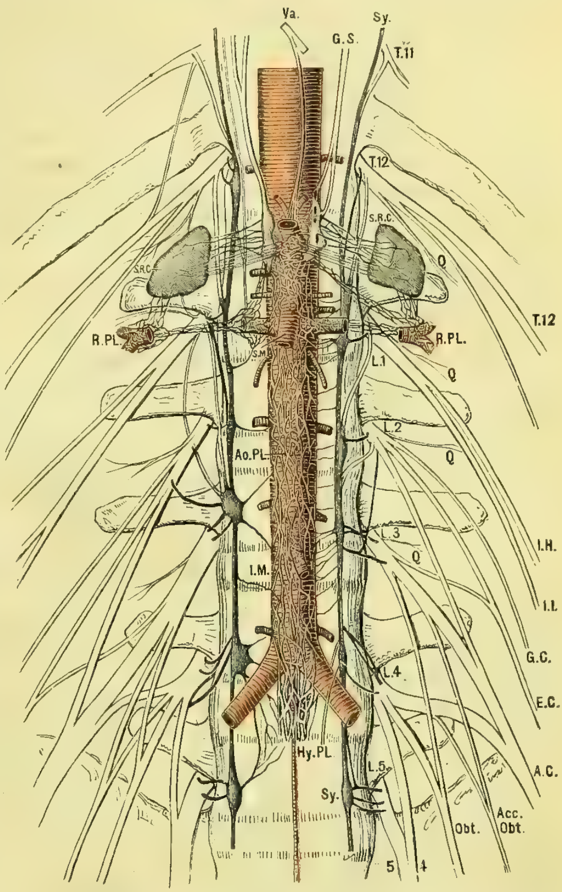


FIG. 480.—THE LUMBAR PORTION OF THE SYMPATHETIC GANGLIATED CORD AND LUMBAR PLEXUS.

T.11, T.12, L.1, L.2, L.3, L.4, L.5, Anterior primary divisions of spinal nerves, with white and gray rami communicantes. Sy, Sympathetic gangliated cord; Va, Vagus nerve; G.S, Great splanchnic nerve, joining semilunar ganglion; S.R.C, Suprarenal capsule and plexus; R.Pl, Renal plexus; Ao.Pl, Aortic plexus; S.M, Superior mesenteric plexus; I.M, Inferior mesenteric plexus; Hy.Pl, Hypogastric plexus; Q, Nerves to quadratus lumborum; I.H, Ilio-hypogastric nerve; I.I, Ilio-inguinal nerve; G.C, Genito-crural nerve; E.C, External cutaneous nerve; A.C, Anterior crural nerve; Acc.Obt, Accessory obturator nerve; Obt, Obturator nerve; 4, 5, Lumbo-sacral cord.

Central Communicating Branches.—**Gray rami communicantes** pass from the gangliated cord to the anterior primary divisions of the lumbar nerves in an irregular manner. One ramus may divide so as to supply branches to two adjacent spinal nerves; or a spinal nerve may be joined by two to five separate gray rami from the gangliated cord.

The gray rami course, along with the white rami, beneath the origin of the psoas magnus muscle, and over the bodies of the vertebræ. Gray rami sometimes pierce the fibres of the muscle.

Peripheral Branches of Distribution.—From the lumbar gangliated cord numbers of small branches arise irregularly, and pass inwards to supply the abdominal aorta, reinforcing the **aortic plexus** (from the solar plexus).

THE SACRAL PART OF THE GANGLIATED CORD.

The sacral part of the gangliated cord, like the cervical and lower lumbar portions of this system, receives no white rami communicantes from the spinal nerves. The **visceral branches** (*pelvic splanchnic*) of the third, and usually, also,

the second or fourth sacral nerves, enter the pelvic plexus without being directly connected with the gangliated cord. These nerves, however, are to be regarded as homologous with the white rami communicantes of the thoracico-lumbar nerves (*abdominal splanchnic*). They convey to the pelvic viscera—(1) motor and inhibitory fibres for rectum, uterus, and bladder, (2) vaso-dilator fibres for the genitals, and (3) secretory fibres for the prostate gland.

This portion of the cord is placed in front of the sacrum, internal to the anterior sacral foramina. It is connected above by a commissural cord with the lumbar portion of the sympathetic, and below it ends in a plexiform union over the coccyx with the cord of the other side, the two being frequently connected by the **ganglion impar** or **coccygeal ganglion**. The number of ganglia is variable; there are commonly four. They are of small size, gradually diminishing from above downwards.

Central communicating branches arise irregularly in the form of **gray rami communicantes** from the sacral ganglia, and join the anterior primary divisions of the sacral and coccygeal nerves.

Peripheral Branches of Distribution.—(1) **Visceral branches** of small size arise from the upper part of the gangliated cord, and pass inwards to join the **pelvic plexus** (see below).

(2) **Parietal branches**, also of small size, ramify over the front of the sacrum, and form, in relation to the middle sacral artery, a plexiform union with branches from the gangliated cord of the other side.

SYMPATHETIC PLEXUSES.

It has already been seen that the peripheral branches of the sympathetic gangliated cord throughout its length are characterised by forming or joining plexuses in their neighbourhood.

The **cervical sympathetic ganglia** and nerves give rise to the carotid and cavernous plexuses; the external carotid, pharyngeal, thyroid, vertebral, and subclavian plexuses; and they send important branches to the cardiac plexuses (described along with the pneumogastric nerve).

The **thoracic ganglia** send branches to join the pulmonary and œsophageal plexuses (described along with the pneumogastric nerve). They form plexuses on the thoracic aorta, and by means of the splanchnic nerves they form the chief source of the solar plexus.

THE SOLAR AND PELVIC PLEXUSES.

These great plexuses serve to distribute nerves to the viscera and vessels of the abdominal and pelvic cavities. Taken together they include three plexuses—the solar plexus, hypogastric plexus, and the pelvic plexuses. They are constituted by peripheral branches of the lower thoracic, lumbar, and upper sacral parts of the gangliated cord of the sympathetic; and they are related to the central nervous system by means of the visceral branches (white rami communicantes) of the lower thoracic and upper lumbar nerves on the one hand, and by the visceral branches of the second and third, or third and fourth sacral nerves, on the other hand. The former series join the sympathetic cord, and reach the solar plexus through the splanchnic nerves mainly, to a lesser extent through the lumbar gangliated cord. The latter series enter the pelvic plexus without connexion with the sympathetic cord. The hypogastric plexus serves as a connecting link between the solar and pelvic plexuses.

The **solar plexus** lies on the posterior abdominal wall behind the stomach. It is composed of three elements: the **cœliac plexus** surrounding the origin of the cœliac axis between the crura of the diaphragm, and two **semilunar ganglia**, each lying on the corresponding crus of the diaphragm, and overlapped by the suprarenal capsule, and on the right side by the inferior vena cava. The plexus is continuous with subordinate plexuses, diaphragmatic, suprarenal, renal, superior mesenteric and aortic; and by means of **the hypogastric nerves** the aortic plexus

becomes continued into the **hypogastric plexus**, which again forms the chief origin of the **pelvic plexuses.**

The **semilunar ganglia** constitute the chief ganglionic centres in the solar plexus. They are irregular in form. They are often partially subdivided, and one detached portion at the lower end is named the **aortico-renal ganglion.** Other small scattered masses of cells are present in the cœliac plexus (**ganglia cœliaca**). At the upper end the semilunar ganglion receives the great splanchnic nerve. The aortico-renal ganglion at its lower end receives the smaller splanchnic nerve. Branches from the ganglion radiate in all directions—inwards to join the cœliac plexus, upwards to form the diaphragmatic plexus, outwards to the suprarenal plexus, downwards to the renal, superior mesenteric, and aortic plexuses.

The **cœliac plexus** forms a considerable plexiform mass surrounding the cœliac axis. It consists of a dense meshwork of fibres with ganglia (g. cœliaca) intermingled, joined by numerous branches from the semilunar ganglion on each side, and by branches from the right pneumogastric nerve. It is continuous below with the superior mesenteric and aortic plexuses. Investing the cœliac axis, it forms subsidiary plexuses which accompany the branches of the artery. The **coronary plexus** supplies branches to the œsophagus and stomach; the **hepatic plexus** supplies branches to the liver and gall-bladder, stomach, duodenum, and pancreas; and the **splenic plexus** sends offsets to the spleen, pancreas, and stomach.

Subordinate plexuses are formed on the aorta and its branches by nerves derived from the solar plexus (semilunar ganglia and cœliac plexus).

a. The **diaphragmatic plexus** consists of fibres arising from the semilunar ganglion, and accompanies the inferior phrenic artery. Besides supplying the diaphragm, it gives branches to the suprarenal plexus, and on the right side to the inferior vena cava, on the left side to the œsophagus. It communicates on each side with the phrenic nerve. At the junction of the plexus and phrenic nerve of the right side a ganglion is formed (**diaphragmatic ganglion**).

b. The **suprarenal plexus** is of considerable size. It is mainly derived from branches of the semilunar ganglion, reinforced by nerves

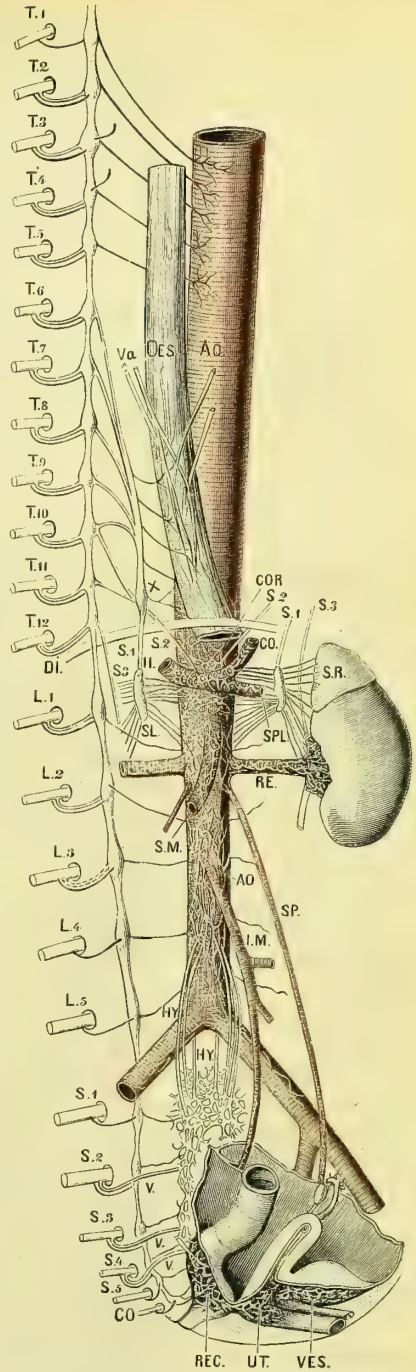


FIG. 481.—THE ARRANGEMENT OF THE SYMPATHETIC SYSTEM IN THE THORAX, ABDOMEN, AND PELVIS.

T.1-12; L.1-5; S.1-5; Co, Anterior primary divisions of spinal nerves, connected to the gangliated cord of the sympathetic by rami communicantes, white (double lines) and gray (single lines); OES, Œsophagus and œsophageal plexus; AO, Aorta and aortic plexus; Va, Vagus nerve joining œsophageal plexus; S.1, Great splanchnic nerve; X, Great splanchnic ganglion; S.2, Small splanchnic nerve; S.3, Least splanchnic nerve; CO, Coronary artery and plexus; SPL, Splenic artery and plexus; H, Hepatic artery and plexus; S.L, Semilunar ganglion; Di, Diaphragm; S.R, Supra-renal capsule; RE, Renal artery and plexus; S.M, Superior mesenteric artery and plexus; SP, Spermatic artery and plexus; I.M, Inferior mesenteric artery and plexus; HY, Hypogastric nerves and plexus; REC, Rectal plexus; UT, Uterine plexus; VES, Vesical plexus; V.V.V, Visceral branches from sacral nerves.

from the lower part of the solar plexus on the capsular arteries. It is joined by branches from the diaphragmatic plexus above and from the renal plexus below. The nerves enter the substance of the suprarenal capsule.

c. The **renal plexus** is derived from (1) branches of the semilunar ganglion, and (2) fibres from the aortic plexus, extending outwards along the renal artery to the hilus of the kidney. It receives also the least splanchnic nerve, and is connected by numerous branches to the suprarenal plexus.

d. The **superior mesenteric plexus** is inseparable above from the cœliac plexus, and is joined on either side by fibres from the semilunar ganglion. It is continuous below with the aortic plexus. A separate detached ganglionic mass (**superior mesenteric ganglion**) is present in the plexus. Accompanying the superior mesenteric artery, the plexus forms subordinate plexuses around the branches of the vessel. The plexuses in the mesentery at first surround the intestinal arteries, but near the intestine they form fine plexuses between the layers of the mesentery, from which branches pass to the wall of the gut. This plexus supplies the small intestine, cæcum, vermiform appendix, ascending and transverse portions of the colon.

e. The **aortic plexus** is the continuation downwards of the solar plexus around the abdominal aorta. It is continuous above with the superior mesenteric and solar plexuses; it is reinforced by the peripheral branches of the lumbar gangliated cord of the sympathetic; and it is connected with the hypogastric plexus below by the **hypogastric nerves.** Besides investing and supplying the aorta, the plexus contributes to various subordinate plexuses on the branches of the artery. It contributes to the suprarenal and renal plexuses, and it gives rise to the spermatic or ovarian and the inferior mesenteric plexuses.

The **spermatic plexus** invests and accompanies the spermatic artery. It is derived from the aortic plexus, and receives a contribution from the renal plexus. It supplies the spermatic cord and testicle.

The **ovarian plexus** in the female arises like the spermatic plexus. It accompanies the ovarian artery to the pelvis, and supplies the ovary, broad ligament, and Fallopian tube. It forms communications in the broad ligament with the **uterine plexus** (from the pelvic plexus), and sends fibres to the uterus.

The **inferior mesenteric plexus** is a derivative from the aortic plexus, prolonged along the inferior mesenteric artery. It forms subordinate plexuses on the branches of the artery (colic, sigmoid, and superior hæmorrhoidal), and is distributed to the descending colon, iliac colon, pelvic colon, and upper part of the rectum.

The **hypogastric nerves** form the continuation of the aortic plexus into the pelvic cavity. They consist of numerous plexiform bundles of nerve fibres which descend along the front and back of the bifurcation of the aorta and the origin of the common iliac arteries, over the sacral promontory, where, becoming inextricably mingled, they constitute the hypogastric plexus.

The **hypogastric plexus** is continued downwards and forwards in front of the sacrum on either side of the rectum, and ends in the pelvic plexuses.

The **pelvic plexuses** are formed as stated by the separation of the hypogastric plexus into two halves on either side of the rectum. Each is joined by fibres from the upper part of the sacral portion of the gangliated cord of the sympathetic, and by the **visceral branches** (white rami communicantes) from the sacral nerves. Accompanying the internal iliac artery and its branches, each pelvic plexus gives off subordinate plexuses for the pelvic viscera.

a. The **hæmorrhoidal plexus** supplies the rectum, and joins the superior hæmorrhoidal plexus from the inferior mesenteric plexus.

b. The **vesical plexus** accompanies the vesical arteries to the bladder-wall. Besides supplying the wall and mucous membrane of the bladder, it forms subordinate plexuses for the lower part of the ureter, the vesicula seminalis, and the vas deferens.

c. The **prostatic plexus** is of considerable size. It is placed on either side of the gland, and besides supplying its substance and the prostatic urethra, sends offsets to the neck of the bladder and the vesicula seminalis. It is continued

forwards on each side to form the **cavernous plexus** of the penis (plex. cavernosus penis). These nerves pierce the layers of the triangular ligament, and after supplying the membranous urethra at the root of the penis, give off branches which enter and supply the corpus cavernosum. The cavernous nerves communicate with branches of the pudic nerve, and give offsets to the corpus spongiosum and the spongy portion of the urethra.

d. The **uterine plexus** passes upwards for a short distance with the uterine artery between the layers of the broad ligament, and is then distributed to the surfaces and substance of the organ. It communicates between the layers of the broad ligament with the ovarian plexus.

The **vaginal plexus** is formed mainly by the visceral branches of the sacral nerves entering the pelvic plexus. It supplies the wall and mucous membrane of the vagina and urethra, and provides a **cavernous plexus** for the clitoris (plex. cavernosus clitoridis). The uterine and vaginal plexuses of the female correspond to the prostatic plexus of the male.

DEVELOPMENT OF THE SYMPATHETIC SYSTEM.

There are two diametrically opposite views of the mode of development of the sympathetic system.

In birds and mammals the first rudiment of the sympathetic cord occurs in the formation of a longitudinal unsegmented column of mesoblastic cells (which stain more deeply than the mesoblast in which they lie) on either side of the aorta, and coterminous with it. This column of cells becomes joined at an early stage by the **visceral branches** of the spinal nerves which grow inwards from the main nerve trunks into the splanchnic area, and result from the division of the nerve into somatic and visceral parts. These visceral branches constitute the **white rami communicantes**. They receive contributions usually from both dorsal and ventral roots, and gradually approaching the above-mentioned column of mesoblastic cells, they become intimately associated with the cells. In some cases fibres of the visceral nerves pass over the cellular column into the splanchnic area without connexion with it (Fig. 483). By the junction of these visceral nerves with the cells of the column, certain cells persist and produce the **ganglia**. The intervening portions of the column, by changes in the cells, and by the addition possibly of fibres belonging to the visceral nerves, give rise to the **commissural cords**. The cellular column, besides producing the gangliated cord, by the further growth of its cells and their extension centrally and peripherally, produces the **gray rami communicantes**, parts of the **peripheral branches**, and the **peripheral** (collateral and terminal) **ganglia**, as well as the medullary portion of the **suprarenal capsule**. The cervical, lower lumbar, and sacral portions of the sympathetic gangliated cord are secondary extensions from the more primitive condition, gradually growing upwards and downwards along the main vessels. These portions of the system are not provided with white rami communicantes. The ganglia of the sympathetic assume their segmented appearance (1) from the persistence of the primitive cells and their connexion with the spinal nerves by means of the white and gray rami communicantes, and (2) from the way in which the primitive column is moulded by the surrounding structures (bones, segmental arteries, etc.).

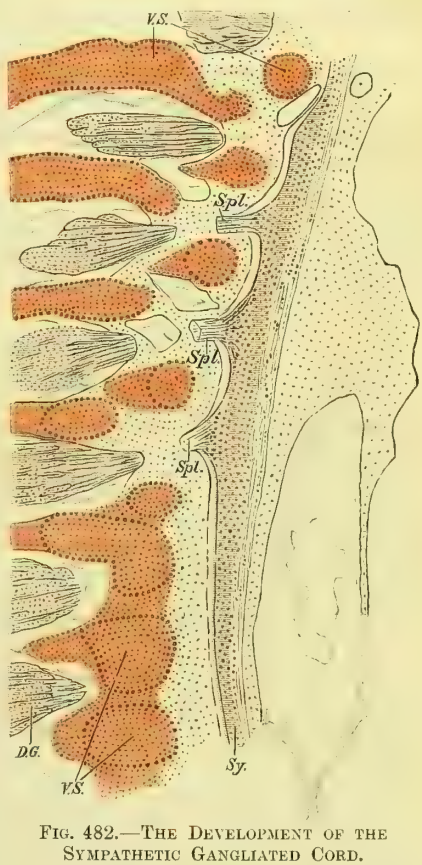


FIG. 482.—THE DEVELOPMENT OF THE SYMPATHETIC GANGLIATED CORD.

Sy, Sympathetic cord; Spl, Splanchnic branches of spinal nerves (white rami communicantes); V.S, Vertebral segments; D.G, Dorsal ganglia.

Another account of the development of the sympathetic system, supported by high authority, describes the gangliated cord as an outgrowth of the dorsal ganglia of the spinal nerves. It is said that each ganglion gives off a bud at its lower end, which, growing inwards into the splanchnic area, becomes attached to the trunk of the spinal nerve just beyond the union of the dorsal and ventral roots. The bud still extending inwards into the splanchnic area, remains associated with the nerve by an attenuated stalk. These buds become the ganglia, which, after reaching their permanent place in the splanchnic area, are supposed to extend upwards and downwards so as to coalesce and form a beaded chain of ganglia. The stalks connecting the ganglia with the spinal nerves become the white rami communicantes. This mode of development does not satisfactorily account for several important features of the sympathetic system—the development of those parts of the gangliated cord which possess no white rami, the absence of a real segmental character in the cord (remarkably shown in the fœtus), and the constancy of continuity in the gangliated cord. No instance is recorded of a hiatus between two ganglia. It is a tempting view on the other hand, as it ascribes to the one germinal layer (epiblast) the formation of all the elements of the nervous system, and it brings the sympathetic ganglia into serial homology with isolated ganglia on the cranial nerves (*e.g.* the ciliary, spheno-palatine, and otic, on the trigeminal nerve).

FIG. 483.—SECTION THROUGH THE SYMPATHETIC GANGLIATED CORD OF AN EMBRYO.

Showing the connexion with the ganglion (Sy) of the white ramus communicans (Spl); (α) a portion of the ramus joining the ganglion; (β) fibres passing over the cord, accompanied by a stream of cells; (γ) continuous with those of the ganglion; (Ao) Aorta.

The Morphology of the Sympathetic System.

From a consideration of its structure, functions, and development, there appear to be two separate structures represented in the sympathetic nervous system—the **spinal** and the **sympathetic elements.** The structure of the system presents a union of two distinct elements—fibres of cerebro-spinal nerves and "sympathetic" cells and fibres. While the function of the gangliated cord and its branches seems to be absolutely dependent upon the cerebro-spinal nervous system, it is certain that the cells and fibres of the sympathetic system possess a vital activity apart from their connexion with the central nervous system. In the development of the sympathetic it is at least highly probable that a mesoblastic rudiment or precursor forms the basis of the sympathetic system, which is secondarily joined by nerve fibres from the roots of the spinal nerves.

Morphologically this part of the nervous system is essentially a longitudinal cord or column, associated with involuntary muscles and glandular tissues, and particularly related to the organs in the splanchnic area. Like other longitudinal structures in the body, and especially like the organs of the splanchnic area, the sympathetic system is not truly segmental. The gangliated cord is only quasi-segmental, the segmentation being attributable to its junction with the visceral branches of the spinal nerves. The peripheral branches from the gangliated cord are not segmental; even the gray rami are not properly metameric, but, like the ganglia, assume a segmental character in consequence of their connexions with the spinal nerves.

The phylogenetic relation of the sympathetic and the cerebro-spinal elements in the system it is impossible to determine. It may be that the sympathetic system is the representative of an ancient architecture independent of the cerebro-spinal nervous system, the materials of which are utilised for a more modern nervous system; or it may be that the correlation of spinal nerves and sympathetic are both the consequences of the formation of new organs and structures in the splanchnic area. Examined in every light, it possesses features which effectually differentiate it from the cerebro-spinal system, although it has become inextricably united with it and subservient to it.

THE ORGANS OF SENSE AND THE INTEGUMENT.

By Robert Howden.

THE NOSE.

The nose constitutes the peripheral part of the organ of smell (organon olfactus), since to the upper portion of its mucous lining the branches of the olfactory nerve are distributed. It consists of an external portion, the outer nose, which projects from the face, and of an internal part, or cavum nasi, which is divided by a vertical septum into right and left cavities or fossæ.

The **outer nose**, or nasus externus, forms a more or less triangular pyramid, of which the upper angle is termed the **root** (radix nasi) and is usually separated from the glabella by a depression, while its **base** (basis nasi), directed downwards, is perforated by the apertures of the nostrils (anterior nares). Its free angle is named the **point** (apex nasi), and the anterior border, joining root and point, is termed the **dorsum nasi**; the upper part of the dorsum is supported by the nasal bones, and is named the **bridge**. The lateral aspects of the nose are continuous with the eyelids above and with the cheeks below, forming, with the latter, a varying angle. Each lateral surface ends inferiorly in a mobile and expanded portion, the **ala nasi**, which forms the outer boundary of the anterior nares and is limited above by a furrow, the **alar sulcus**. The skin covering the nose is thin and movable over the root, but thick and adherent over the point and alæ, where it contains numerous large sebaceous glands.

The arterial supply of the outer nose is derived from the facial and ophthalmic arteries, and its veins drain themselves into the facial and ophthalmic trunks. Its lymphatics follow the course of the facial vein and open into the submaxillary lymphatic glands. The facial nerve supplies its muscles, while the sensory nerves for the skin are the infratrochlear and nasal branches of the ophthalmic nerve and the infraorbital branch of the superior maxillary nerve.

The nose presents great variety as to its size and shape, and certain well-defined types, such as aquiline, Grecian, etc., are described. The relation which its breadth, measured across the alæ, bears to its length, measured from root to point, is termed the cephalometric nasal index, and is expressed thus:

$$\frac{\text{greatest breadth} \times 100}{\text{greatest length.}}$$

In white races this index is below 70 (leptorhines); in yellow races, between 70 and 85 (mesorhines); and in black races, above 85 (platyrhines).

CARTILAGES OF THE NOSE.

In addition to the bony skeleton of the nose there are five chief cartilages (cartilagines nasi) which contribute to the production and maintenance of its shape. These are named—(*a*) the cartilage of the septum, and (*b*) the upper and lower lateral cartilages, on each side.

The **cartilage of the septum** (cartilago septi nasi, Fig. 484) is of an irregularly quadrilateral form. Its postero-superior edge is attached to the mesethmoid; its postero-inferior margin to the vomer and intermaxillary crest. Its antero-superior

border is thick and is fixed above to the back of the internasal suture; below the level of the nasal bones it is continued, on either side, into the upper lateral cartilages, which may be looked upon as its wing-like expansions. The lower part of this

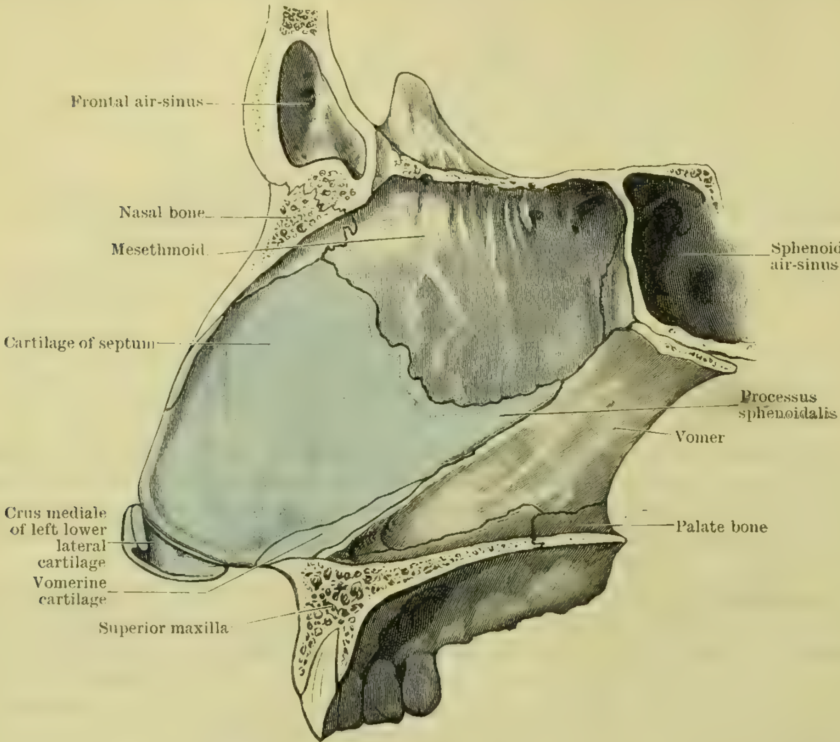


FIG. 484.—LATERAL VIEW OF NASAL SEPTUM.

border is separated by a furrow from the upper lateral cartilages and extends downwards between the inferior lateral cartilages, to which it is attached by fibrous tissue. In this fibrous tissue a small sesamoid cartilage is usually seen on each side of the middle line. Its antero-inferior border is short and is attached by fibrous tissue to the mesial plates of the lower lateral cartilages, while its anterior angle is rounded and does not reach as far as the point of the nose. The lowest part of the nasal septum is not formed by the septal cartilage, but by the mesial plates of the lower lateral cartilages and by the integument, and, being freely movable, is termed the **septum mobile nasi**. The cartilage of the septum may be prolonged backwards (especially in children) as a tongue-like process into the angle between the vomer and ethmoid. This process, varying in width from 4-6 mm., is named the **processus sphenoidalis septi cartilaginei**, and sometimes reaches as far as the body of the sphenoid.

Lying along the lower edge of the cartilage of the septum, and best seen on making a coronal section of the nose, are a couple of elongated cartilaginous strips. Each measures from 6-12 mm. in length, is attached to the vomer, and is named the **vomerine cartilage** (cartilago vomeronasalis, Jacobsoni).

The **upper lateral cartilage** (cartilago nasi lateralis, Figs. 485, 486) is triangular in shape and situated immediately below the nasal bone, to which and to the superior maxilla its thin posterior border is attached. Its anterior edge is thick and its upper part is directly continuous with the cartilage of the septum. Its lower margin is joined by fibrous tissue to the upper edge of the lower lateral cartilage.

The **lower lateral cartilage** (cartilago alaris major, Figs. 485, 486, 487) encircles the anterior part of the nostril and assists in keeping it open. It consists of two plates, outer and inner, which are continuous with each other in a rounded angle at the point of the nose. The **outer plate**, or crus laterale, is oval in shape and is attached to the upper lateral cartilage and to the superior maxilla by fibrous tissue.

Continuous with its postero-superior angle are two or three small cartilaginous pieces (cartilagines alares minores), while sometimes a horizontal furrow cuts off a narrow linear part from its upper aspect. The lower edge of the outer plate does not reach down as far as the lateral boundary of the nostril, the ala being devoid of cartilage and composed merely of fatty and connective tissue covered by skin. The **inner plate,** or crus mediale (Fig. 487), bounds the inner aspect of the nostril and lies in the septum mobile nasi, below the anterior part of the cartilage of the septum. The mesial plates of the two cartilages are separated in front by a notch, which corresponds with the point of the nose, and each curves slightly outwards posteriorly and ends in a rounded extremity.

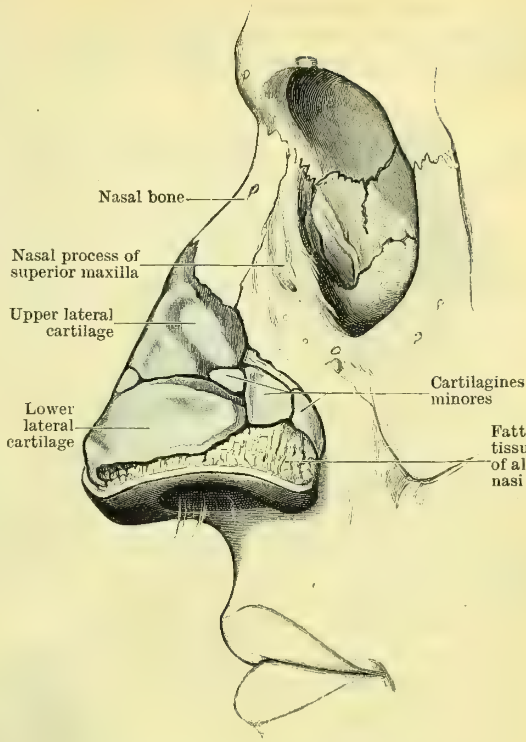


FIG. 485.—PROFILE VIEW OF THE BONY AND CARTILAGINOUS SKELETON OF THE NOSE.

NASAL FOSSÆ.

The **nasal fossæ** (Fig. 488) are two in number and are placed one on each side of the middle line. They extend from the anterior to the posterior nares or choanæ, and open through the latter into the naso-pharynx. Their bony boundaries are described in the section on Osteology (p. 158). On the lateral wall of each are found the orifices of the frontal, ethmoidal, sphenoidal, and maxillary sinuses, together with that of the nasal duct.

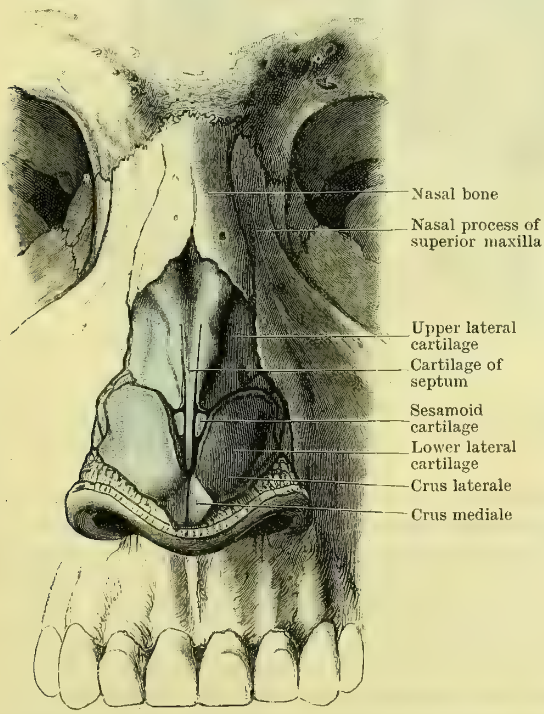


FIG. 486.—FRONT VIEW OF THE BONY AND CARTILAGINOUS SKELETON OF THE NOSE.

Immediately above the aperture of the nostril is a slightly expanded area, the **vestibule** (vestibulum nasi). This is bounded externally by the lower lateral cartilage, and, internally, by the lower part of the septum, and is prolonged towards the tip of the nose as a small pouch, termed the **ventricle.** Partly subdivided by a curved ridge, the vestibule is lined by skin and contains hairs and sebaceous glands. The hairs, or vibrissæ, springing from its lower half, are stout and curved downwards to guard the entrance to the nostril. The upper part of the vestibule is smooth and is limited above and behind by a slightly-marked arched prominence, the **limen nasi,** beyond which the fossa is lined by mucous membrane.

The nasal fossa above and behind the vestibule is divided into two parts, viz. an upper or olfactory, and a lower or respiratory region. The **olfactory part,** or regio olfactoria, is a narrow slit-like cavity, and comprises the region of the superior turbinated bone, together with a corresponding portion of the septum. The **respiratory part,** or regio respiratoria, is expanded, and includes the lower and remaining parts of the fossa.

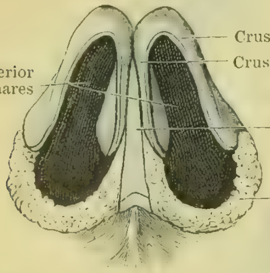


Fig. 487.—Cartilages of Nose from Below.

Inner Wall or Septum Nasi (Fig. 484).—Where the bony septum is deficient, below and in front, the gap is filled by the septal cartilage. Until the seventh year the nasal septum lies, as a rule, in the mesial plane, but after this age is very often deflected to one or other side—more frequently to the right—the deflection taking place along the line of junction of the vomer and mesethmoid. In the floor of the fossa, close to the lower edge of the septal cartilage and immediately over the incisive foramen, a slight depression, the **recessus nasopalatinus,** may be seen. It is directed downwards and forwards, and indicates the position of the communication which originally existed between the nasal and buccal cavities. In the septum, a little above and in front of this depression, is a minute orifice, not always recognisable, from which a blind pouch extends upwards and backwards for a distance of from 2 to 9 mm. This is the rudimentary **organ of Jacobson** (organon vomeronasale) and is supported by the vomerine cartilage. In many of the lower animals this organ is well developed (Fig. 489), and in them probably plays a part in the sense of smell, as to it a branch of the olfactory nerve is distributed.

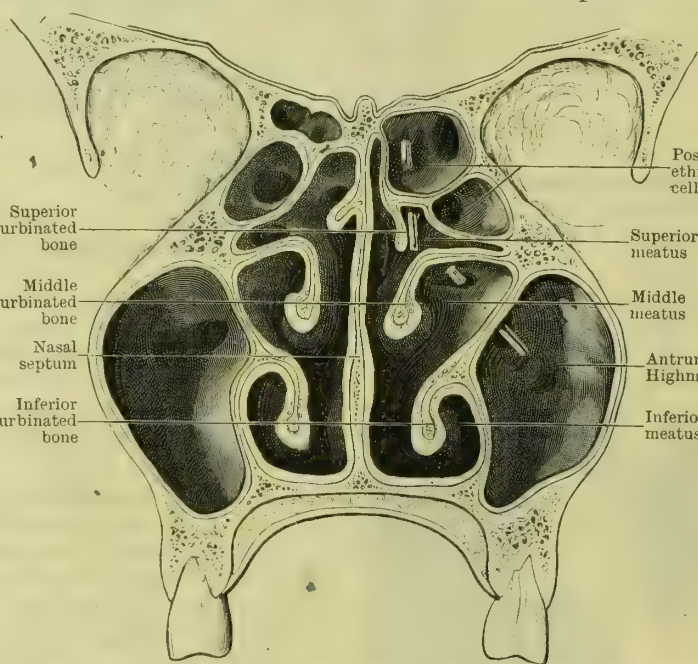


Fig. 488.—Coronal Section through Nasal Fossæ; Anterior Half of Section Viewed from Behind.

Outer Wall (Fig. 490).—Above the superior turbinated bone is a narrow recess, the **recessus spheno-ethmoidalis,** into the posterior part of which the sphenoidal air-sinus opens. The **superior meatus** (meatus nasi superior) is a short oblique fissure, directed downwards and backwards, under cover of the superior turbinated bone; into its antero-superior portion the posterior ethmoidal cells open by one or more orifices. The **middle meatus** (meatus nasi medius), situated externally to the middle turbinated bone, is a roomy passage, and is continued forwards into a slightly depressed area termed the **atrium meatus nasi,** which lies immediately above the vestibule. The atrium is limited above and in front by a low ridge, the **agger nasi,** the representative of the naso-turbinal found in many animals. On raising or removing the

middle turbinated bone a rounded elevation, the **bulla ethmoidalis**, is seen. This varies in size and is directed downwards and forwards, whilst opening either on it or above it are the orifices of the middle ethmoidal cells. Curving upwards and forwards, below and in front of the bulla ethmoidalis, is a deep, narrow groove, the **hiatus semilunaris**, into which the anterior ethmoidal cells and the antrum of Highmore open. The opening of the latter is placed near the roof of the antrum, and may be duplicated. The middle meatus extends upwards and forwards, and, becoming narrowed, is continued into the **infundibulum** or channel leading into the frontal air-sinus. The **inferior meatus** (meatus nasi inferior) lies below the inferior turbinated bone, under cover of the anterior part of which is found the slit-like orifice of the nasal duct (see p. 698).

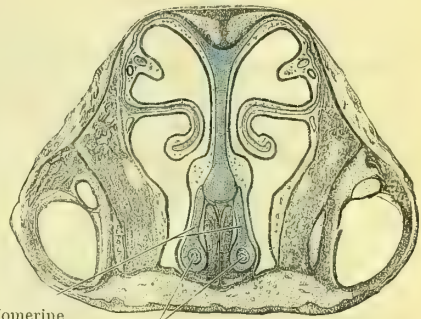


FIG. 489.—SECTION THROUGH NOSE OF KITTEN, showing position of Jacobson's organ.

Mucous Membrane (membrana mucosa nasi).—The Schneiderian or nasal mucous membrane is thick, highly vascular, and firmly bound to the subjacent periosteum and perichondrium. It is continuous, through the choanæ, with the mucous lining of the naso-pharynx; through the

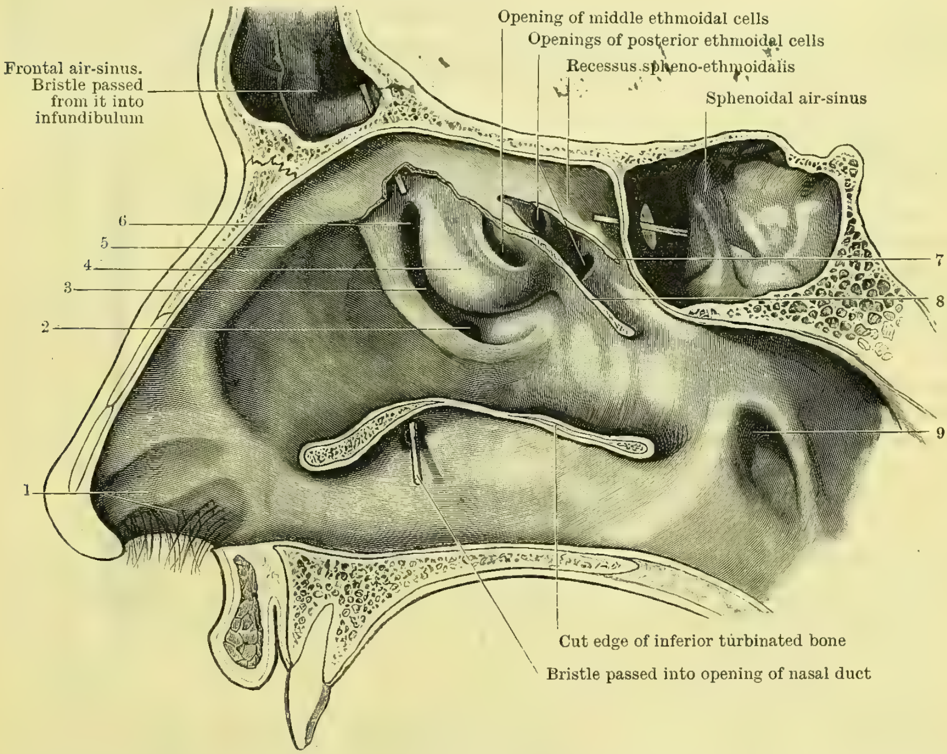


FIG. 490.—VIEW OF THE OUTER WALL OF THE NOSE—THE TURBINATED BONES HAVING BEEN REMOVED.

1. Vestibule.
2. Hiatus semilunaris.
3. Opening of antrum of Highmore.
4. Bulla ethmoidalis.
5. Agger nasi.
6. Opening of anterior ethmoidal cells.
7. Cut edge of superior turbinated bone.
8. Cut edge of middle turbinated bone.
9. Pharyngeal orifice of Eustachian tube.

nasal duct, with the conjunctiva; and, through the apertures leading into the air-sinuses, with the delicate lining of these cavities.

Throughout the respiratory region it is covered by columnar, ciliated epithelium, interspersed amongst which are goblet or mucin cells, whilst between the bases of the columnar cells smaller pyramidal cells are interpolated. It contains a

freely anastomosing venous plexus, which, in some parts, *e.g.* over the inferior turbinated bones, forms a kind of cavernous tissue (plexus cavernosus concharum). Many acinous glands, secreting a watery fluid, are embedded in it, and are especially large and numerous in the posterior half of the nasal fossæ, while in children it contains a considerable amount of adenoid tissue.

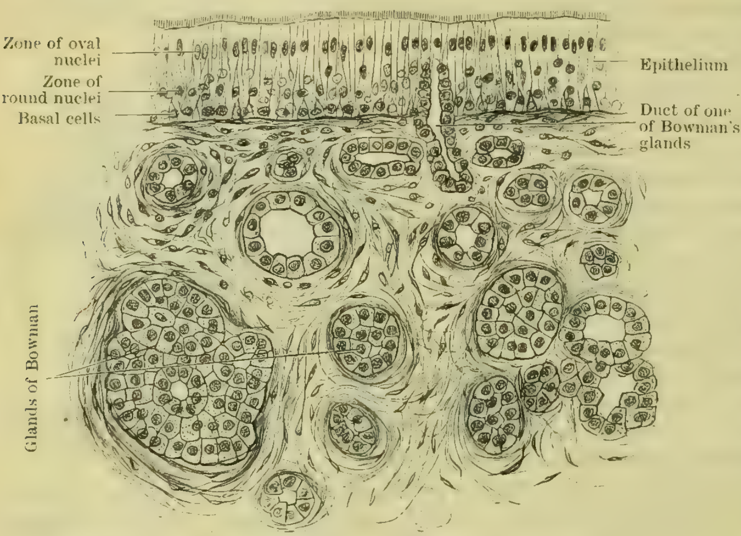


FIG. 491.—SECTION THROUGH THE OLFACTORY MUCOUS MEMBRANE.

In the olfactory region the mucous membrane is yellowish in colour and more delicate, and is covered by non-ciliated columnar epithelium (Figs. 491, 492). Embedded in it are numerous tubular and often branched glands, the **glands of Bowman** (gl. olfactoriæ); these are lined by polygonal cells and open by fine ducts on its free surface. The epithelium covering the olfactory region consists of: (1) supporting cells, (2) olfactory cells, and (3) basal cells.

1. **Supporting Cells.**—The outer part of these cells is columnar in shape and contains fine granules of yellow pigment, whilst the deeper portion is attenuated and frequently branched. They contain elliptical or oval nuclei, which are situated at the deep end of the columnar part of the cell and form what is termed the zone of oval nuclei.

2. **Olfactory Cells.**—They are spindle-shaped and lie between the deeper, attenuated parts of the supporting cells; their nuclei are circular and form the zone of round nuclei. Each cell gives off a peripheral and a central process, the former of which is rod-like and ends on a level with the free extremities of the supporting cells, where it is surmounted by a pencil of short filaments, termed the **olfactory hairs**. A fine membrane, the membrana limitans externa, covers in many animals the free surface of the epithelium, and is pierced by the olfactory hairs and by the ducts of Bowman's glands.

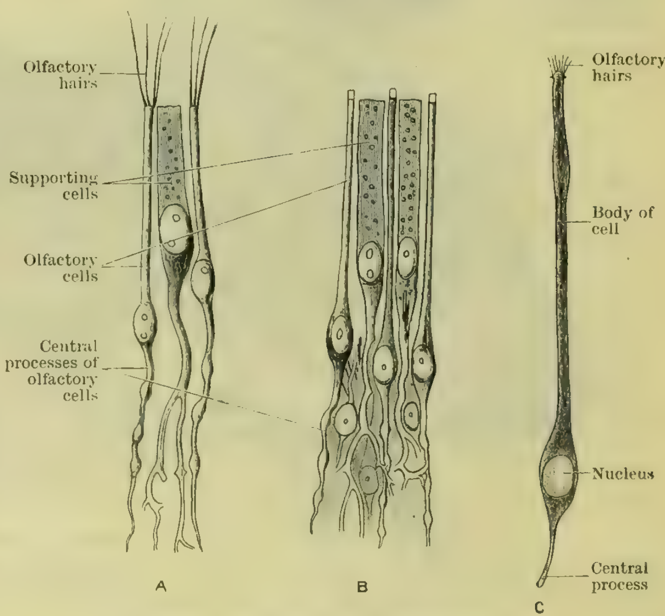


FIG. 492.—OLFACTORY AND SUPPORTING CELLS.
A. Frog, B. Human } M. Schultze. C. Human (v. Brunn).

The central process is a very delicate varicose filament, which passes inwards

and is continuous with a fibril of the olfactory nerve. Each of these nerve fibrils probably retains its independence from its point of origin in an olfactory cell to its termination in the olfactory bulb, in the glomerular layer of which it forms a free arborisation.

3. **Basal Cells.**—These cells are branched, and lie on a basement membrane between the deep extremities of the supporting and olfactory cells.

Olfactory Nerves.—These nerves traverse the cribriform plate of the ethmoid bone, and are at first lodged in the bony canals or grooves situated on the inner and outer walls of the olfactory area, and, reaching the deep surface of the mucous membrane, are continued into the central processes of the olfactory cells. The olfactory nerves possess no medullary sheath.

The fifth cranial nerve supplies branches of ordinary sensation to the nasal mucous membrane as follows: The septum is chiefly supplied by the naso-palatine nerve, but its posterior part receives some filaments from Meckel's ganglion and the Vidian nerve, and its anterior portion from the nasal branch of the ophthalmic. The outer wall is supplied—(1) by the upper nasal branches of the Vidian nerve and Meckel's ganglion; (2) by the lower nasal branches derived from the anterior palatine; and in front by (3) the outer division of the nasal branch of the ophthalmic. The floor and anterior part of the inferior meatus are supplied by a nasal branch of the anterior superior dental nerve.

Blood-vessels.—Arteries. The chief artery of the nose is the spheno-palatine branch of the internal maxillary artery. This reaches the nasal cavity through the spheno-palatine foramen, and divides into—(*a*) posterior nasal, which ramifies over the turbinated bones and sends branches to the antrum and to the frontal and ethmoidal cells; and (*b*) naso-palatine, the artery of the septum. Twigs are given to the upper portion of the cavity by the anterior and posterior ethmoidal arteries, while its posterior part receives some small branches from the descending palatine vessel. The nostrils are supplied by the lateral nasal branch of the facial, and by the septal artery of the superior coronary. The antrum is partly supplied by the infraorbital artery, whilst the sphenoidal sinus gets its chief supply from the pterygo-palatine vessel. The **veins** form a dense plexus almost resembling cavernous tissue in structure. This condition is well seen in the respiratory region, and especially so over the middle and inferior turbinated bones and on the lower part of the septum. The venous blood is carried in three chief directions, viz. *forwards* into the facial vein, *backwards* into the spheno-palatine vein, and *upwards* into the ethmoidal veins. The ethmoidal veins communicate with the ophthalmic veins and the veins of the dura mater; further, an ethmoidal vein passes up through the cribriform plate of the ethmoid, and either opens into the venous plexus of the olfactory bulb or directly into one of the veins of the orbital part of the frontal lobe of the brain. The **lymphatics** form an irregular network in the superficial part of the mucous membrane, and can be injected from the subdural or subarachnoid space. The larger vessels are directed backwards towards the choanæ and are collected into two trunks, of which the larger passes to a lymphatic gland in front of the axis vertebra and the smaller to one or two glands situated near the great cornu of the hyoid bone.

The development of the nose is described in the section which deals with "General Embryology" (p. 36).

THE EYE.

The eyeball or globe of the eye (bulbus oculi) constitutes the chief part of the organ of sight (organon visus); but, associated with its description, certain accessory structures, such as the eyelids and the lachrymal apparatus, fall to be considered.

THE EYEBALL.

Situated in the anterior part of the orbital cavity, the eyeball is protected in front by the eyelids and by their mucous lining, the conjunctiva, and is pierced behind by the optic nerve, or nerve of sight, which spreads out to form its innermost tunic, the retina. The tendons of the ocular muscles are attached to its outer surface a short distance in front of its equator, while its posterior two-thirds are enveloped by a loose membrane, termed the capsule of Tenon, or fascia bulbi, which separates it from the surrounding orbital fat.

The eyeball is not quite spherical, being composed of the segments of two spheres, viz. an anterior, transparent, corneal segment, possessing a radius of 7 or 8 mm., and a posterior, opaque, scleral segment, with a radius of about 12 mm.

(Fig. 493). The anterior or corneal segment, in consequence of its shorter radius, projects as a dome in front of the scleral portion, the union of the two parts being indicated externally by a slight groove, the sulcus scleræ. The central

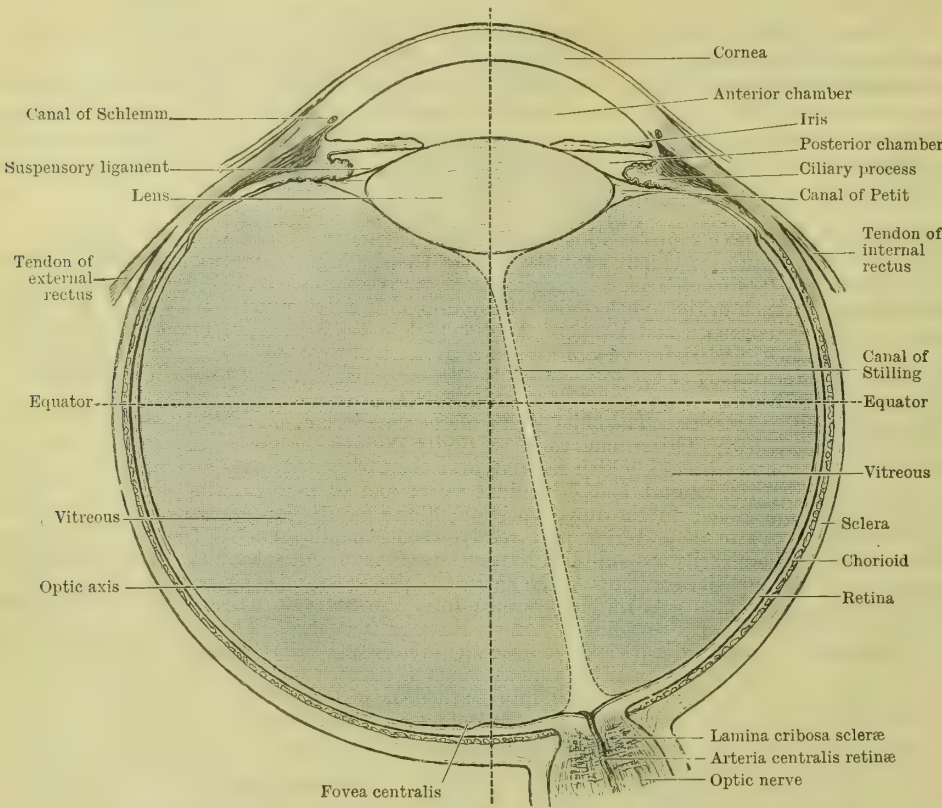


FIG. 493.—DIAGRAM OF A HORIZONTAL SECTION THROUGH LEFT EYEBALL AND OPTIC NERVE (four times enlarged).

points of the anterior and posterior curvatures of the eyeball constitute respectively its **anterior** and **posterior poles**, while a straight line joining the two poles is termed its **sagittal axis** (axis optica). The axes of the two eyeballs are almost parallel, diverging only slightly in front; but the axes of the optic nerves converge behind, and, if prolonged backwards, would meet in the region of the dorsum sellæ of the sphenoid. An imaginary line encircling the globe midway between its two poles is named its **equator**, and **meridional lines** (meridiani) may be drawn from pole to pole at right angles to the equator. Its sagittal and transverse diameters are nearly equal—about 24 mm.; its vertical diameter is about 23·5 mm. All three diameters are rather less in the female than in the male, but the size of the eyeball is fairly constant in the same sex. What are popularly described as large eyes owe their apparent increase in size to a greater prominence of the globe and to a wider fissure between the eyelids.

At birth the eyeball is nearly spherical and has a diameter of about 17·5 mm. By the age of puberty this has increased to 20 or 21 mm., after which it rapidly reaches its adult size.

The eyeball (Fig. 493) consists of three concentric tunics or coats, contained within which are three transparent refracting media. The three tunics are: (1) an outer fibrous coat, the sclero-cornea, consisting of an opaque posterior part, the **sclera**, and a transparent anterior portion, the **cornea**; (2) an intermediate vascular, pigmented, and partly muscular tunic, the tunica vasculosa oculi, comprising from behind forward the **chorioid**, the **ciliary body**, and the **iris**; (3) an internal nervous tunic, the **retina**. The three refracting media are named,

from before backwards, the **aqueous humour**, the **crystalline lens**, and the **vitreous body**.

SCLERA.

The **sclera**, sclerotic coat, or white of the eye, is a firm, opaque membrane, which forms something like the posterior five-sixths of the outer tunic. Thickest posteriorly (about 1 mm.), it thins at the equator to 0·4 mm.-0·5 mm., and again increases to 0·6 mm. near the sulcus scleræ. In the child it is thinner than in the adult and presents a bluish appearance, caused by the pigment of the chorioid shining through it, while in old age it assumes a yellowish tinge. Its outer surface is covered by a layer of endothelium and is in contact with the capsule of Tenon—a lymph space, **the suprascleral lymphatic space**, only intervening. In front of the equator it is roughened by the attachment of the tendons of the ocular muscles, while its anterior part is covered by mucous membrane, the conjunctiva. Its deep surface presents a brownish colour and is loosely attached to the chorioid, except at the optic entrance and in the neighbourhood of the sulcus scleræ. It is pierced behind by the optic nerve, the entrance for which is funnel-shaped, wide behind and narrow in front, and is situated 1 mm. below and 3 mm. to the nasal side of the posterior pole of the eyeball. The fibrous sheath of the nerve blends with the outer part of the sclera, while the nerve bundles pass through a series of orifices; this perforated portion is named the **lamina cribrosa scleræ**. Around the entrance of the optic nerve are some fifteen or twenty small apertures for the passage of the ciliary nerves and short ciliary arteries. The two long posterior ciliary arteries pierce it, one on either side, some little distance from the optic entrance; while a little behind the equator are four openings, two above and two below, for the exit of veins, called **venæ vorticosæ**. Near the sulcus scleræ it is perforated by the anterior ciliary arteries. Its inner surface is lined by flattened endothelial cells; and between it and the chorioid is an extensive lymph space, the **spatium perichorioideale**, which is traversed by the ciliary nerves and arteries just mentioned, and by an irregular meshwork of fine, pigmented, connective tissue, the **lamina fusca**, which loosely attaches the sclera to the chorioid. At the corneo-scleral junction the fibrous tissue of the sclera passes continuously into that of the cornea, and in the deeper part of this junction there is a circular canal, the sinus venosus scleræ, or **canal of Schlemm**, which communicates externally with the scleral veins, and internally, through numerous small openings, with the anterior chamber of the eyeball. The sclera consists of bundles of white fibrous tissue, together with some fine elastic fibres, the bundles forming equatorial and meridional layers, which interlace with each other. Numerous spaces containing connective tissue cells and migratory cells exist between the fibres. Pigmented cells are plentiful in the lamina fusca, and a few are also found in the tissue of the sclera, near the optic entrance and in the region of the corneo-scleral junction. The sclera receives its blood-supply from the short posterior ciliary and anterior ciliary arteries, while its veins open into the venæ vorticosæ and anterior ciliary veins. The cell spaces play the part of lymphatics, and communicate with the perichorioidal and suprascleral lymph spaces. Its nerves are derived from the ciliary nerves, which, after losing their medullary sheath, pass between the fibrous bundles; their exact mode of ending is, however, not accurately known.

CORNEA.

The **cornea** forms the anterior sixth of the outer tunic and is transparent, in order to admit light into the interior of the eyeball; its index of refraction is from 1·33 to 1·35. Its anterior surface (facies anterior) is covered by a stratified epithelium, continuous with that which lines the conjunctiva; its posterior surface (facies posterior) is directed towards the anterior chamber of the eyeball and is in contact with the aqueous humour. Its degree of curvature varies in different individuals; it is always greater in youth than in old age, and is, as a rule, slightly greater in the vertical than in the horizontal plane. It diminishes also from its centre to its periphery, and is less on the nasal than on the temporal side

of the anterior pole. The anterior surface of the cornea is almost, but not quite, circular, measuring 11 mm. vertically and 11·9 mm. transversely, while its posterior surface is circular and has a diameter of 13 mm. Its periphery is overlapped by the tissue of the sclera as the glass of a watch is overlapped by the metal rim, with, however, this essential difference, that the tissue of the cornea is directly continuous with that of the sclera.

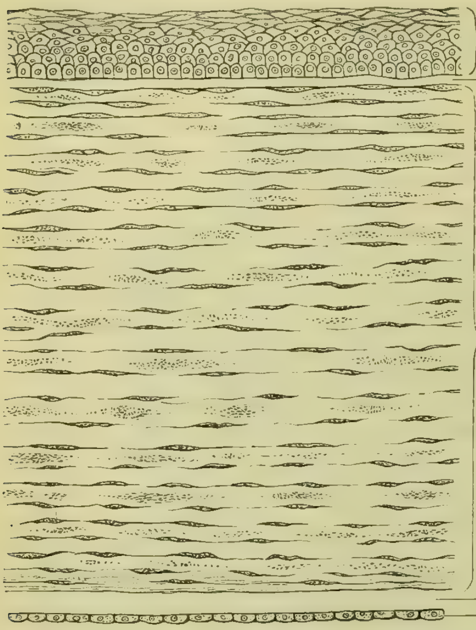


Fig. 494.—Vertical Section of Cornea (magnified).

The cornea consists, from before backwards, of the following strata, viz. (Fig. 494):—

1. A layer of stratified epithelium.
2. An anterior elastic lamina.
3. The substantia propria.
4. A posterior elastic lamina.
5. A layer of endothelium.

1. The **layer of stratified epithelium** (epithelium corneæ) is continuous with that which covers the free surface of the conjunctiva and consists of six or eight strata of nucleated cells. Deepest of all is a single layer of perpendicularly-arranged columnar cells, the flattened and often-expanded bases of which rest on the anterior elastic lamina, while their opposite ends are rounded and contain the nuclei. Superficial to this layer are three or four strata of nucleated, polygonal cells, the majority of which exhibit finger-like processes which join with the corresponding processes of neighbouring cells. The more superficial layers assume the form of nucleated squames. The entire thickness of this stratified epithelium is about 45 μ at the centre and about 80 μ at the periphery of the cornea.

2. The **anterior elastic lamina** (lamina elastica anterior, Bowmani) is from 19-20 μ thick, and may be regarded merely as a differentiation of the outer part of the substantia propria from which it is with difficulty separated. It is not stained yellow by picrocarmine, thus differing from true elastic tissue, and its degree of development varies in different animals.

3. The **substantia propria** presents, in a fresh condition, a homogeneous appearance; but, with the assistance of reagents, it is seen to consist of modified connective tissue, with some few elastic fibres. An amorphous interstitial substance binds the fibres into bundles, and, in turn, cements the bundles into lamellæ, which are directly continuous with the fibrous tissue of the sclera. The fibres of any one lamella cross those of adjacent lamellæ almost at right angles, while the superimposed lamellæ are joined by sutural fibres and by amorphous substance. Between the lamellæ are found the **cell spaces** or **lacunæ** of the cornea—irregularly stellate in shape, and communicating freely with each other by means of fine canaliculi. The corneal cells or corpuscles are contained in these lacunæ, without, however, completely filling them, the remainder of the cavities being occupied by lymph. These cells are nucleated, flattened, and star-like, and their branched processes join those of neighbouring cells in the canaliculi. Migratory or lymph cells are also found in the cell spaces.

In old age a grayish opaque ring, 1½ to 2 mm. in breadth, is frequently seen near the periphery of the cornea; it is termed the **arcus senilis**, and results from a deposit of fat granules in the lamellæ and corneal corpuscles.

4. The **posterior elastic lamina** (lamina elastica posterior, Demoursi, Descemeti) is a clear, structureless membrane, covering the posterior aspect of the substantia

propria and possessing a thickness of 6-8 μ at the centre and 10-12 μ at the periphery of the cornea. Less firmly attached than the anterior elastic lamina, it may be stripped off, when it will be found to roll up with its attached surface inwards. Between the ages of twenty and thirty small wart-like projections appear on its deep surface, near its periphery, and these increase in size and number as years advance, so that in old age the membrane may attain a thickness of 20 μ. Towards the periphery of the cornea the lamina divides into three sets of fibres — anterior, middle, and posterior. The anterior fibres pass behind the canal of Schlemm into the sclera, the middle give attachment to the ciliary muscle, while the posterior are continued as radiating and anastomosing fibres into the substance of the iris, and constitute the **ligamentum pectinatum iridis.** A number of irregular spaces, the **spaces of Fontana**, or spatia anguli iridis, exist between the fibres of this pectinate ligament. Better developed in the horse and ox than in man, these spaces are lined by a prolongation of the corneal endothelium, and communicate internally with the anterior chamber and with the lymph spaces of the iris, and externally with the canal of Schlemm.

5. The **layer of endothelium** (endothelium cameræ anterioris) consists of a single stratum of nucleated, flattened, polygonal cells, which present a fibrillar structure and are continued as a lining to the spaces of Fontana; this layer of endothelium is also reflected on to the anterior surface of the iris.

Vascular and Nervous Supply of the Cornea.—In the fœtus the cornea is traversed, almost as far as its centre, by capillaries; but in the adult it is devoid of blood-vessels, except near its margin. The capillaries of the conjunctiva and sclera pass into this marginal area for a distance of about 1 mm., where they terminate in loops. All the remainder of the cornea is nourished by the lymph which circulates in its cell spaces and canaliculi.

The **nerves** of the cornea, discovered by Schlemm, are derived from the ciliary nerves. Around its periphery they form a plexus, the plexus annularis, from which fibres pass into the cornea, where, after a distance of 1 or 2 mm., they lose their medullary sheath and ramify in the substantia propria, forming what is termed the fundamental or stroma plexus. Perforating fibres (fibræ perforantes) extend from this plexus through the anterior elastic lamina and form a sub-epithelial plexus, from which fine filaments ramify between the epithelial cells as far as the superficial layers. From the annular and stroma plexuses fibrils pass to the substantia propria and come into close relation with the corneal corpuscles.

VASCULAR AND PIGMENTED TUNIC.

The middle, vascular, and pigmented tunic (tunica vasculosa oculi) comprises, from behind forwards, the chorioid, the ciliary body, and the iris (Fig. 493).

The **chorioid** (chorioidea) intervenes between the sclera and the retina, reaching as far forwards as the ora serrata of the latter (p. 689). Dark brown or black in colour, it is pierced posteriorly by the optic nerve, and is here firmly attached to the sclera. Thicker behind than in front, its outer surface is flocculent and is connected to the sclera by the ciliary vessels and nerves, and by the loose lamina fusca. Its inner surface is smooth and adheres to the outermost or pigmented layer of the retina.

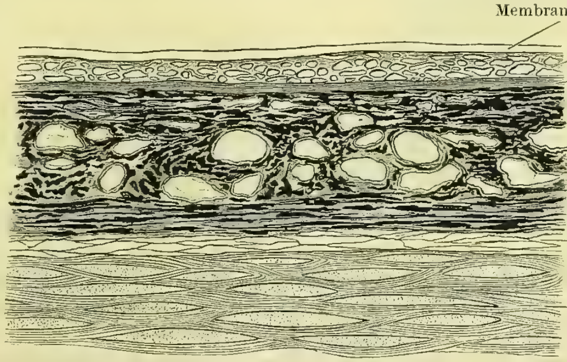


FIG. 495.—VERTICAL SECTION OF CHORIOID AND INNER PART OF SCLERA.

The chorioid consists of blood-vessels and branched pigment cells embedded in a loose connective tissue, and presents from without inwards three layers, viz.: (*a*) the lamina suprachorioidea; (*b*) the proper tissue of the chorioid; and (*c*) a thin transparent membrane, the lamina basalis or membrane of Bruch (Fig. 495).

1. The **lamina suprachorioidea** resembles the lamina fusca of the sclera and

consists of a series of fine non-vascular lamellæ, each containing a delicate network of elastic fibres, amongst which are stellate, pigmented cells, together with amœboid cells. The spaces between the laminæ are lined with endothelium, and together form the spatium perichorioideale, already referred to (p. 683).

The **proper tissue of the chorioid** consists of blood-vessels and numerous pigmented cells, supported by connective tissue and elastic fibres, together with some smooth muscular fibres. Its outer part contains the larger blood-vessels and is named the **lamina vasculosa**, while its inner portion is composed of a network of fine capillaries, and is termed the **lamina choriocapillaris**; these two laminæ are joined by a thin **intermediate stratum**. The arteries of the chorioid are derived from the short posterior ciliary vessels, which pierce the sclera around the optic entrance and form a wide-meshed plexus in the lamina vasculosa. Their circular muscular coat is well developed, and longitudinal muscular fibres are also present in the larger branches. The veins, destitute of muscular tissue, are superficial to the arteries; they are surrounded by perivascular lymphatic sheaths and converge to form whorls, which open into the venæ vorticosæ. In the tissue between the blood-vessels are numerous stellate, flattened, and pigmented cells.

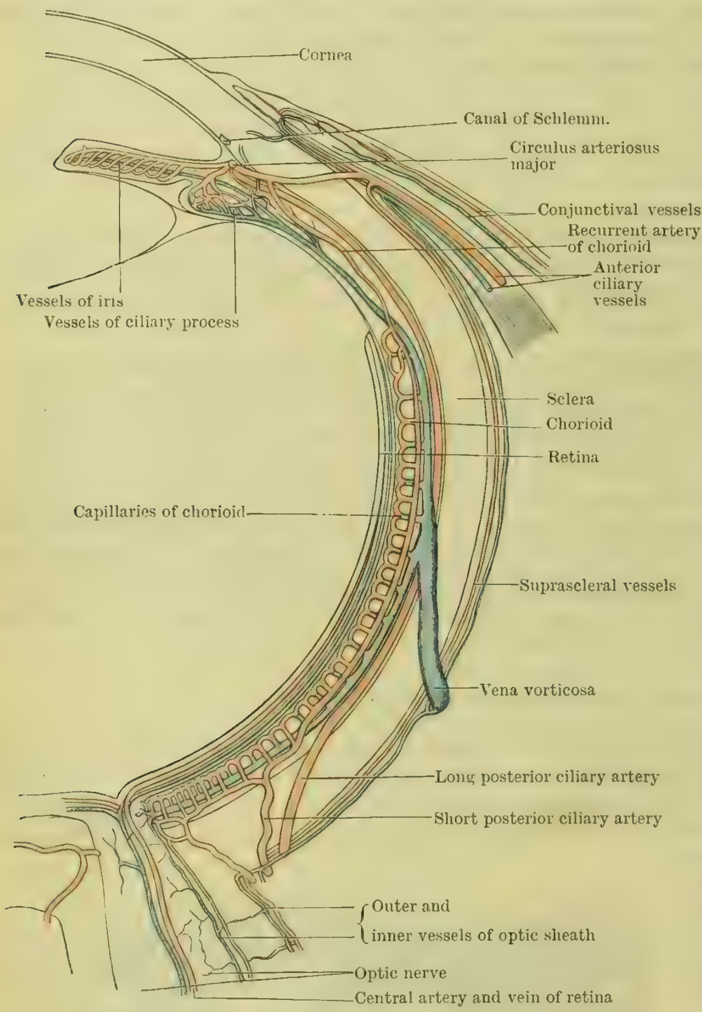


FIG. 496.—DIAGRAM OF THE CIRCULATION IN THE EYE (Leber).

The **lamina choriocapillaris**, or membrane of Ruysch, is composed essentially of small capillaries, which form an exceedingly close network, embedded in a finely granular or almost homogeneous tissue. The **intermediate stratum** between the lamina vasculosa and lamina choriocapillaris consists of a network of delicate elastic fibres and contains almost no pigment cells; it is lined next the lamina choriocapillaris by a continuous layer of endothelium.

The **lamina basalis**, or membrane of Bruch, is transparent and nearly structureless. Its outer surface presents a trellis-like network of fibres, which unite it to the membrane of Ruysch, while its inner surface is smooth and is in contact with the pigmented layer of the retina.

Tapetum.—In many animals a brilliant iridescent appearance is seen on the postero-external part of the chorioid, to which the name **tapetum** is applied. Absent in man, it may be due, as in the horse, to a markedly fibrous condition of the stratum intermedium (tapetum fibrosum), or, as in the seal, to the presence of some five or six layers of flattened iridescent cells lying immediately outside the lamina choriocapillaris (tapetum cellulosum).

The **ciliary body** (corpus ciliare) connects the chorioid to the circumference of the iris (Fig. 497), and presents the following three zones, viz.: (*a*) the orbiculus ciliaris, (*b*) the ciliary processes, and (*c*) the ciliary muscle.

The **orbiculus ciliaris** forms a zone of about 4 mm. in width immediately adjoining the chorioid, and exhibits numerous radially-arranged ridges. The **ciliary processes** (processus ciliares), about seventy in number, form a circle of radial thickenings, each of a somewhat triangular shape. The base of the triangle is directed forwards towards the equator of the lens, while the apex is continuous behind with some three or four ridges of the orbiculus ciliaris. They vary in size, the largest having a length of 2-5 mm. The structure of the orbiculus ciliaris and ciliary processes is similar to that of the chorioid, but the capillaries are larger and more tortuous, and there is no lamina choriocapillaris. The deep aspect of the ciliary processes is covered by two strata of columnar epithelium, the anterior layer of which is pigmented; these two strata form a direct continuation forwards of the retina and constitute the **pars ciliaris retinæ**. This epithelium is invaginated to form more or less tubular glands, which may take a share in the secretion of the aqueous humour.

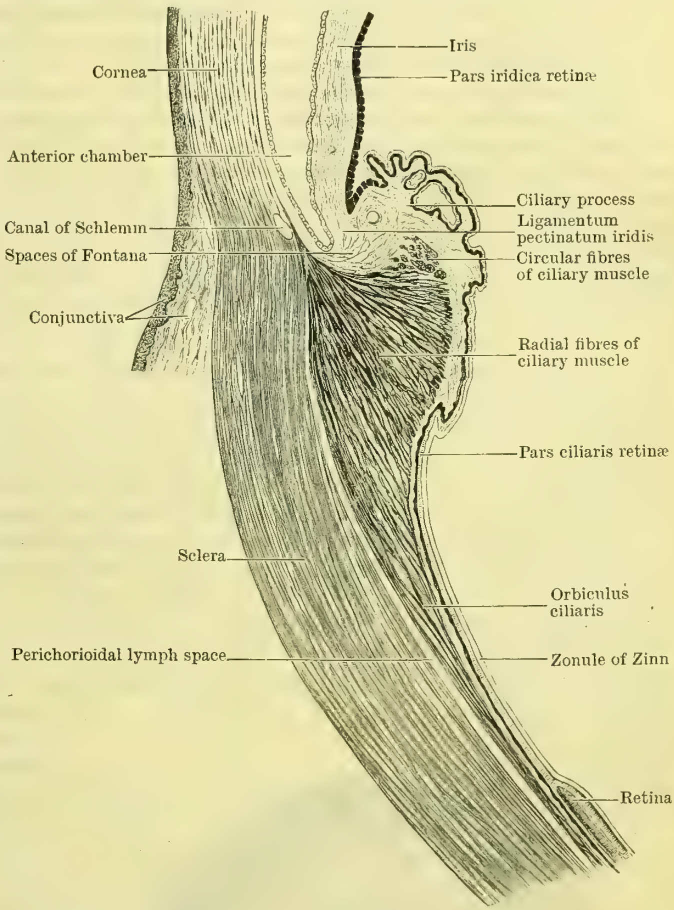


FIG. 497.—SECTION THROUGH CILIARY REGION OF EYEBALL.

The **ciliary muscle** (m. ciliaris) is triangular on antero-posterior section, and consists of two sets of fibres—radial and circular (Fig. 497). The **radial fibres** (fibræ meridionales, Brückei) spring from the corneo-scleral junction behind the canal of Schlemm and from the ligamentum pectinatum iridis, and radiate backwards, to be attached to the ciliary processes and orbiculus ciliaris. When they contract the chorioid is drawn forwards and the lens becomes more convex, owing to the relaxation of its suspensory ligament (see p. 693). The **circular fibres** (fibræ circulares, Mülleri) form a triangular zone behind the ligamentum pectinatum iridis, close to the periphery of the iris, and also extend backwards under the radial fibres. Considerable individual differences are found as to the degree of development of these two portions of the ciliary muscle. The radial fibres are always more numerous than the circular fibres, the latter being absent or rudimentary in myopic eyes, but well developed, as a rule, in hypermetropic eyes.

The **iris** forms a contractile diaphragm in front of the lens and is pierced a little to the nasal side of its centre by an almost circular aperture, the **pupil** (pupilla), which, during life, is continually varying in size in order to regulate the amount of light admitted into the interior of the globe. It divides the space between the cornea and lens into two parts, which are filled by the aqueous humour, and named respectively the **anterior and posterior chambers** of the eyeball. Its

peripheral border, or **margo ciliaris**, is directly continuous with the ciliary body, and, through the medium of the ligamentum pectinatum iridis, with the posterior elastic lamina of the cornea. Its free edge, or **margo pupillaris**, forms the circumference of the pupil, and rests upon, but is not attached to the anterior surface of the capsule of the lens.

The distinctive colour of the eye, in different individuals, depends on the arrangement of the pigment in the iris; in the blue eye this is limited to the posterior surface of the iris, but in the brown or black eye it is also scattered throughout its stroma. In the albino the pigment is entirely absent, and the red appearance of the eye in such a case is produced by the network of blood-vessels in the iris.

The pupil is closed, during the greater part of fœtal life, by a thin transparent vascular membrane, the **membrana pupillaris**, continuous with the pupillary margin of the iris. Its vessels, derived partly from the vessels of the iris and partly from those of the capsule of the lens, converge towards the middle of the membrane, near which they form loops so as to leave the central part non-vascular. About the seventh month the vessels begin to be obliterated from the centre towards the circumference, and this is followed by a thinning and absorption of the membrane, which becomes perforated by the aperture of the pupil. This perforation gradually enlarges, and at birth the membrane has entirely disappeared, although in exceptional cases it persists.

On the anterior surface (facies anterior) of the iris is a layer of flattened endothelium, placed on a basement membrane, and continuous with that which lines the spaces of Fontana and covers the back of the cornea. Depressions or crypts are here and there seen in which the endothelium and basement membrane are absent, and are, by some, regarded as stomata, through which the lymphatics of the iris communicate with the cavity of the anterior chamber. Its posterior surface (facies posterior) is covered by a basement membrane, on which are placed two layers of columnar, pigmented epithelium, continuous with the pars ciliaris retinæ and termed the **pars iridica retinæ**. The proper tissue of the iris, or **stroma iridis**, consists of delicate connective tissue and elastic fibres, with pigmented cells, blood-vessels, nerves, and non-striped muscle.

The **blood-vessels of the iris** (Fig. 498) are derived from the long and anterior ciliary arteries. The long ciliary arteries, two in number, pierce the sclera on the inner and outer side of the optic nerve respectively, and extend forwards between the sclera and chorioid towards the ciliary margin of the iris. Here each divides into an upper and a lower branch, and the resulting four branches anastomose in the form of a circle, termed the **circulus arteriosus major** This circle is joined by a varying number of anterior ciliary arteries derived from the lachrymal and muscular branches of the ophthalmic artery, and, after supplying the ciliary muscle, sends converging branches inwards towards the aperture of the pupil, around which a second circle, the **circulus arteriosus minor**, is formed. The veins proceed towards its ciliary margin, and communicate with the veins of the ciliary processes and with the canal of Schlemm. The convergence of the blood-vessels towards the aperture of the pupil gives to the anterior surface of the iris a striated appearance.

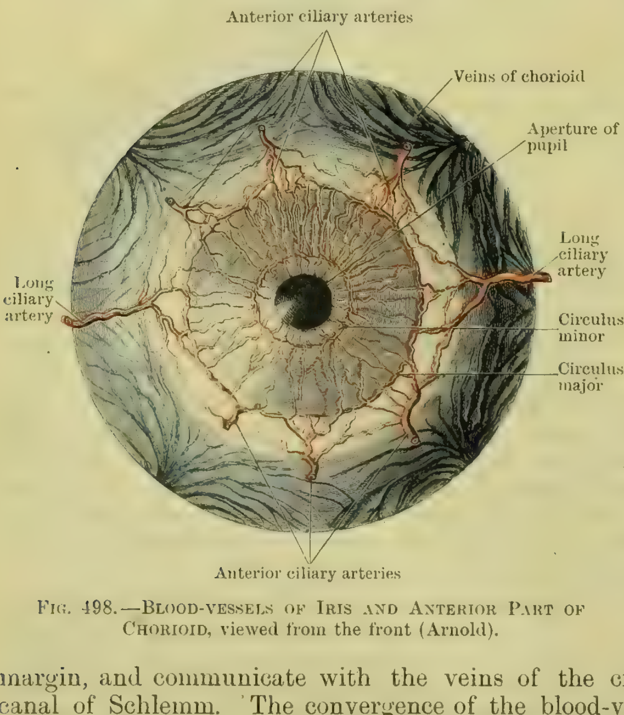


FIG. 498.—BLOOD-VESSELS OF IRIS AND ANTERIOR PART OF CHORIOID, viewed from the front (Arnold).

The **non-striped muscular fibres** are arranged in two sets: (*a*) circular, (*b*) radial. The **circular fibres** form a band around the pupillary aperture, by the contraction of which its size is lessened, and hence it is termed the **m. sphincter pupillæ.** The **radial fibres** extend outwards from the sphincter to the ciliary margin and constitute the **m. dilatator pupillæ.** Many anatomists regard the radial fibres, in man and most mammals, as being elastic and not muscular. In animals, where the radial fibres are muscular, the degree of their development varies considerably; they are feebly marked in the rabbit, but well developed in the bird, and still more so in the otter.

The **nerves of the chorioid and iris** are derived from the long and short ciliary nerves. The former, two or three in number, are branches of the nasal nerve; the latter, varying from eight to fourteen, are derived from the ciliary ganglion. Piercing the sclera around the optic entrance the nerves traverse the perichorioidal lymph space, where they form a plexus, rich in nerve-cells, from which filaments are supplied to the blood-vessels of the chorioid. In front of the ciliary muscle a second plexus, also rich in nerve-cells, is formed, which supplies the muscle itself and sends filaments into the iris as far as its pupillary margin, for the supply of its muscular fibres and blood-vessels. The sphincter pupillæ is supplied by the third cranial nerve, whilst filaments from the sympathetic are distributed to the dilatator pupillæ.

THE RETINA.

The **retina**, or nervous tunic of the eyeball, is a soft, delicate membrane, in which the fibres of the optic nerve are spread out. It consists of two strata, viz.: (*a*) an outer, pigmented layer (stratum pigmenti), attached to the chorioid; and (*b*) an inner nervous lamina, the retina proper, in contact with the hyaloid membrane of the vitreous body, but only attached to it at the optic entrance and in the region of the ciliary processes. Expanding from the entrance of the optic nerve the retina appears to end, a short distance behind the ciliary body, in a wavy border, the **ora serrata.** Here its nervous elements cease and the membrane becomes suddenly thinned, but a delicate continuation of it is prolonged over the posterior aspect of the ciliary body and iris. This continuation consists of the stratum pigmenti, together with a layer of columnar epithelium, and constitutes the **pars ciliaris retinæ** and **pars iridica retinæ**, already referred to (pp. 687 and 688). The portion behind the ora serrata is termed the "physiological retina" or **pars optica retinæ**, and its thickness gradually diminishes from 0·4 mm., near the optic entrance, to 0·1 mm. at the ora serrata. Viewed from the front it presents, at the posterior pole of the eyeball, and therefore directly in the axis of the globe, a small yellowish spot, the **macula lutea.** Somewhat oval in shape, the greatest or transverse diameter of the macula measures from 2-3 mm.; its central part is depressed and named the **fovea centralis.** About 3 mm. to the nasal side of the posterior pole and about 1 mm. below its level is a whitish, circular disc, the **optic disc**, or porus opticus, which corresponds with the entrance of the optic nerve and has a diameter of about 1·5 mm. The circumference of the optic disc is slightly raised and is named the **colliculus nervi optici**, while its depressed central portion is termed the **optic cup**, or excavatio papillæ nervi optici. The optic disc consists merely of nerve fibres, the other layers of the retina being absent, and constitutes the "blind spot" of physiologists.

The nervous layer of the retina is transparent during life, but becomes opaque and of a greyish colour soon after death. If an animal is kept in the dark before the removal of its eyeball, the retina presents a purple tinge, due to the presence of a colouring matter named **rhodopsin** or **visual purple**, which, however, becomes rapidly bleached on exposure to sunlight. This colouring matter is absent from the macula lutea, and also over a narrow zone, 3-4 mm. in width, near the ora serrata.

Structure of the Retina (Figs. 499, 500, 501).—The nervous elements of the retina are supported by non-nervous or **sustentacular fibres**, and are arranged in seven layers, to which must be added the stratum pigmenti.

Our conception of the minute structure of the retina, as of all nervous tissues, has of late years been greatly advanced by the discoveries of Ramon y Cajal, on whose observations the following description is based (Fig. 500):—

The layers from within outwards, *i.e.* from vitreous body to chorioid, are:

1. Layer of nerve fibres (stratum opticum).
2. Layer of nerve cells (ganglionic layer).
3. Inner molecular or inner plexiform layer.
4. Inner nuclear layer or layer of inner granules.
5. Outer molecular or outer plexiform layer.
6. Outer nuclear layer or layer of outer granules.
7. Layer of rods and cones (bacillary layer).
8. Layer of pigmented epithelium (stratum pigmenti).

1. **Layer of nerve fibres or stratum opticum.**—The fibres of this stratum are nearly all centripetal and are mostly continuations of the non-medullated axons of the cells in the ganglionic layer. Some, however, are centrifugal and end in branched clubbed extremities in the inner molecular or inner nuclear layers.

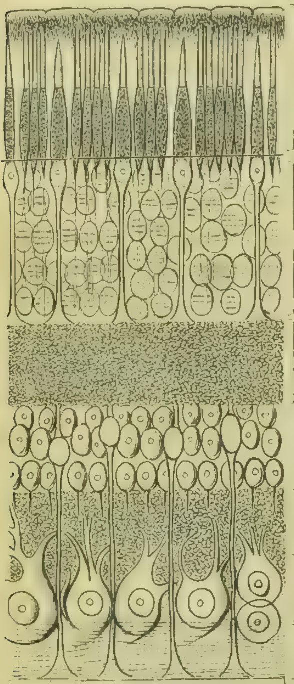


FIG. 499.—DIAGRAMMATIC SECTION OF THE HUMAN RETINA (modified from Schultze).

2. **Ganglionic or nerve-cell layer.**—The cells of this stratum vary in size, are oval or pyriform in shape, and form a single layer, except at the macula lutea, where several strata are present. Each cell contains a large nucleus, and gives off, from its inner aspect, an axon, which is continued as a fibre of the nerve fibre layer. From the outer surface of each cell numerous dendrites arise, which form arborisations in the inner molecular layer. The cells may be divided into unistratified, multistratified, and diffuse, according as their dendrites ramify in one or in several strata of the inner molecular layer or extend throughout nearly its whole thickness.

3. **Inner molecular or inner plexiform layer.**—This is chiefly constituted by the interlacement of the dendritic arborisations of the cells of the ganglionic layer with those of the inner nuclear layer, and has been divided by Ramon y Cajal into five strata. It sometimes contains horizontal cells or spongioblasts, whose branched processes ramify in it.

4. **Inner nuclear layer or layer of inner granules.**—This is the most complicated of the retinal strata and consists of numerous cells, which may be divided into three groups, viz.: (*a*) bipolar cells, (*b*) horizontal cells, and (*c*) spongioblasts.

(*a*) The **bipolar cells** are fusiform and nucleated, and each gives off an external and an internal process. The internal processes terminate in flattened tufts at different levels in the inner molecular layer, while the external produce an abundant ramification in the external zone of the outer molecular layer. These bipolar cells are divided into rod bipolars, cone bipolars, and giant bipolars. The **rod bipolars** end peripherally in vertical arborisations around the button-like ends or spherules of the rod fibres, and, centrally, in branched extremities, which mostly become applied to the cells of the ganglionic layer. The **cone bipolars** end peripherally in flattened arborisations in the outer molecular layer in contact with the ramifications of the cone fibres, and, centrally, ramify in some one of the five strata of the inner molecular layer. The **giant bipolars** form, peripherally, an extensive horizontally-arranged arborisation in the outer molecular layer; centrally, they ramify in one or other of the strata of the inner molecular layer.

(*b*) The **horizontal cells** are of two varieties: (1) small, flattened, star-like cells, lying immediately below the outer molecular layer and sending a tuft of dendrites outwards towards the bases of the cone fibres, while their axons are directed horizontally for a variable distance; (2) large, irregular cells, lying internal to the above and ending in finger-like ramifications in the outer molecular layer. Their axons run horizontally for some distance and end in extensive varicose arborisations under the spherules of the rod fibres.

(*c*) The spongioblasts are situated in the innermost part of the inner granular layer and have not yet been shown to possess axons. Their dendrites ramify in the inner

molecular layer, it may be in one stratum (stratified spongioblasts) or in several strata (diffuse spongioblasts).

5. **Outer molecular or outer plexiform layer.**—This is constituted by the

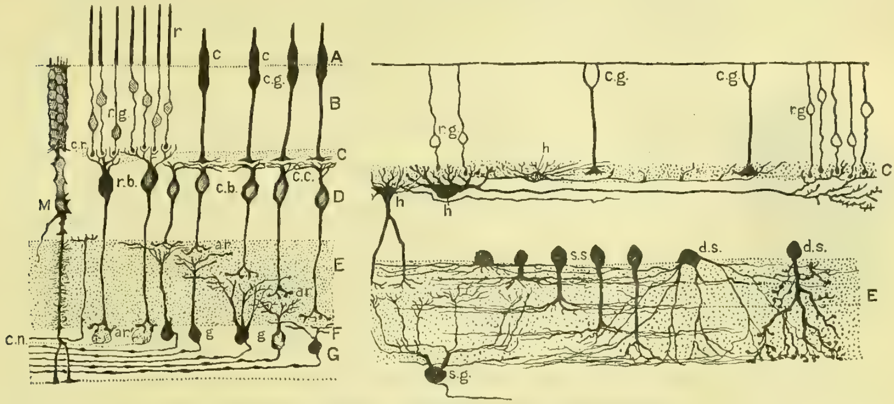


FIG. 500.—PERPENDICULAR SECTIONS OF MAMMALIAN RETINA (Cajal).

A, Layer of rods and cones ; B, Outer nuclear layer ; C, Outer molecular layer ; D, Inner nuclear layer ; E, Inner molecular layer ; F, Ganglionic layer ; G, Stratum opticum ; *r*, rods ; *c*, cones, *r.g*, rod granules ; *c.g*, cone granules ; *r.b*, rod bipolars ; *c.b*, cone bipolars ; *c.r*, contact of rod bipolars with the spherules of the rod fibres ; *c.c*, contact of cone bipolars with the branches of the cone fibres ; *ar*, internal arborisation of cone bipolars ; *ar′*, internal arborisation of rod bipolars ; *c.n*, centrifugal nerve fibre ; *h*, horizontal cells ; *s.s*, stratified spongioblasts ; *d.s*, diffuse spongioblasts ; *s.g*, stratified ganglion cell ; M, Sustentacular fibre of Müller.

interlacement of the dendrites of the bipolar and horizontal cells, just described, with the spherules of the rod fibres and the ramifications of the foot plates of the cone fibres. It is divided into two strata : (*a*) *external*, indicating the contact of the rod bipolars with the spherules of the rod fibres ; (*b*) *internal*, the line of contact between the cone bipolars and the branches of the cone fibres.

6. **Outer nuclear layer or layer of outer granules.**—This is made up of clear granules somewhat resembling those of the inner nuclear layer, but divisible into two kinds ; (*a*) cone granules, (*b*) rod granules. The **cone granules** are the larger, and each contains an oval nucleus ; they lie immediately inside the outer limiting membrane, through which they are continuous with the cones of the next layer. Each is prolonged internally as a straight fibre, which, on reaching the outer molecular layer, expands to form a foot-plate, from which several horizontal fibrils are given off. The **rod granules** are far more numerous than the cone granules, and each contains a small oval nucleus, which is transversely striated. Their outer processes are continuous, through the outer limiting membrane, with the rods of the next layer ; while their inner processes pass into the outer molecular layer and end in free, unbranched spherules amongst the arborisations of the rod bipolars.

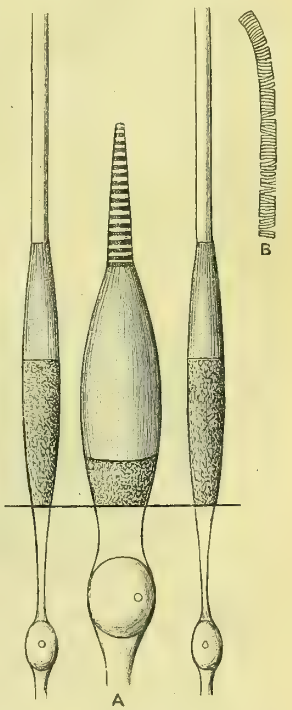


FIG. 501.

A, A cone and two rods from the human retina (modified from Max Schultze) ; B, Outer part of rod separated into discs.

7. **Layer of rods and cones.**—This consists of two sets of structures, viz. **rods** and **cones**. Except at the macula lutea the rods are far more numerous than the cones and assume the form of elongated cylinders, while the cones are shorter than the rods and taper externally to fine points. Each rod and cone consists of two segments—inner and outer. The inner segment of the rod only slightly exceeds in diameter its outer segment, whereas the inner segment of the cone greatly exceeds its outer part. The inner segments of both rods and cones have an affinity for staining reagents and consist of a basal homogeneous portion and an outer longitudinally-striated part, the proportion of the latter to the former being greater in the cones than in the rods. The outer segments have not the same affinity for reagents, but tend to break transversely into numerous discs (Fig. 501, B). The colouring matter,

rhodopsin, already referred to, is found only in the outer segments of the rods, the terminal parts of which extend into the layer of pigmented epithelium.

8. **Layer of pigmented epithelium** (stratum pigmenti).—This consists of a single stratum of cells which, on surface view, are hexagonal (Fig. 502), their outer flattened surfaces being firmly attached to the chorioid. When seen in profile the outer part of each cell contains a large oval nucleus and is devoid of pigment, while the inner portion is filled with pigment and extends as a series of thread-like processes amongst the outer segments of the rods and cones. When the eye is kept in the dark the pigment accumulates near the outer part of the cell, but, when exposed to light, it streams in between the rods and cones.

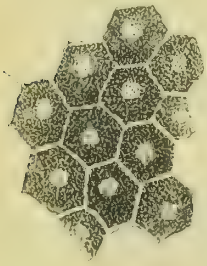


Fig. 502.—Pigmented Epithelium of Human Retina (viewed from the surface).

It will be seen from the foregoing description that there is no direct continuity between the nervous elements which form the different layers of the retina. In the inner molecular layer there is merely an interlacement between the dendrites of the ganglionic layer and the arborisations of the cells of the inner granular layer, and a similar interlacement in the outer molecular layer between the rod and cone elements and the processes of the outer granules.

Sustentacular fibres of the retina (fibræ Mülleri).—These support the nervous structures and extend from within outwards through the thickness of the retina as far as the bases of the rods and cones (Fig. 500, M). They begin at the inner surface of the nerve fibre layer in single, or forked, expanded bases, by the apposition of which a delicate membrane, the **membrana limitans interna**, is formed. In the ganglionic layer they give off a few lateral branches, and, on passing through the inner nuclear layer, supply lateral ramifications amongst the inner granules for their support; in this part of each fibre there is seen an oval nucleus. In the outer nuclear layer they break up into a network of fibrils which surround the rod and cone fibres, and end externally at the bases of the rods and cones in a delicate membrane, the **membrana limitans externa.**

Structure of the macula lutea and fovea centralis.—The yellow colour of the macula is due to the presence of pigment in the inner layers of the retina. At the circumference of the macula the nerve fibre layer is greatly thinned and the rods are few in number; the ganglionic layer, on the other hand, is much thickened and may contain from seven to nine strata of cells, while the outer granular layer is also thicker and its bipolar cells have an oblique direction. At the fovea centralis the retina is much thinned, since here its nerve fibre and ganglionic layers are absent and its other strata greatly attenuated. The stratum pigmenti, on the other hand, is thicker and its pigmentation more pronounced. The cone nuclei are situated some distance internal to the outer limiting membrane, and thus the thin inner and outer granular layers are in apposition. There are no rods, and the cones, closely crowded together, are narrower and their outer segments more elongated than elsewhere, so that the line of their bases, indicated by the membrana limitans externa, presents a convexity directed forwards. The fovea centralis and macula lutea are spoken of by the physiologist as the "region of distinct vision."

Structure of the ora serrata.—Here the nervous layers of the retina suddenly cease; the layer of rods and cones first failing, to be immediately followed by the disappearance of the other nervous strata. In front of the ora serrata the retina is prolonged over the ciliary processes in the form of two layers of cells: (*a*) an inner layer of columnar epithelium, and (*b*) an outer, consisting of the stratum pigmenti, the two forming the pars ciliaris retinæ. The same two layers are prolonged over the back of the iris, where both are pigmented and form the pars iridica retinæ.

Vessels of the retina.—The retina is supplied by the **arteria centralis retinæ**, a branch of the ophthalmic artery, which pierces the sheath of the optic nerve about three-quarters of an inch behind the eyeball and makes its appearance in the centre of the optic disc. Here it divides into an upper and a lower branch, and each of these again bifurcates into an internal, or nasal, and an external, or temporal, branch. The resulting four branches ramify towards the periphery of the retina, and are named the superior and inferior temporal and the superior and inferior nasal arteries. The temporal arteries pass outwards above and below the macula lutea, to which they give small branches; these do not, however, extend as far as the fovea centralis, which is devoid of blood-vessels. The macula also receives two small arteries (superior and inferior macular) directly from the porus opticus. The larger vessels run in the nerve fibre layer near the membrana limitans interna and form two capillary networks—an inner, in the nerve fibre layer, and

an outer, in the inner nuclear layer. The inner network arises directly from the arteries and sends numerous small branches to the outer network, from which the veins take origin. The vessels do not penetrate deeper than the inner granular layer, nor do the arteries anastomose, except through the capillary plexuses. The **veins** follow the course of the arteries; they have no muscular coats, but consist merely of a layer of endothelial cells, outside which is a perivascular lymphatic sheath, surrounded by delicate retiform tissue.

REFRACTING MEDIA OF THE EYEBALL.

The **vitreous body** (corpus vitreum) is a transparent jelly-like substance situated between the crystalline lens and the retina, and occupying the posterior four-fifths of the globe (Fig. 493). In front it presents a deep concavity, the **fossa patellaris**. for the reception of the posterior convexity of the lens. It is enclosed within a thin transparent membrane, the **membrana hyaloidea**, which is in contact with the membrana limitans interna of the retina and adherent to it at the optic entrance. The portion of the membrana hyaloidea in front of the ora serrata is thickened and strengthened by radial fibres, and is termed the **zonule of Zinn**, or zonula ciliaris. Situated behind the ciliary body, the zonula is radially folded and presents a series of alternating furrows and elevations. The ciliary processes are received into, and are firmly adherent to, the furrows, with the result that, if removed, some of their pigment remains attached to the zonula. The elevations of the zonula are not attached to the interciliary depressions, but are separated by a series of lymph spaces (recessus cameræ posterioris); these may be regarded as diverticula of the posterior chamber with which they communicate. As the zonula approaches the equator of the lens it splits into two chief layers, viz.: (*a*) a thin posterior lamina, which covers that portion of the membrana hyaloidea which lines the fossa patellaris; and (*b*) a thicker anterior layer, termed the **suspensory ligament** of the lens (Fig. 493), which blends with the front of the lens capsule a short distance from its equator. Scattered fibres of this ligament are also attached to the equator itself and to the regions immediately anterior and posterior to it. By this suspensory ligament the lens is retained in position and its convexity varies inversely with the degree of tension of the ligament. The radial fibres of the ciliary muscle, by pulling forward the ciliary processes and the attached zonule of Zinn, relax the ligament, and thus allow the lens to become more convex. Behind the suspensory ligament a sacculated lymph space surrounds the equator of the lens; it is named the **canal of Petit**, and may easily be inflated on introducing a fine blow pipe through the suspensory ligament (Fig. 503). The hyaloid membrane of the vitreous body is not only adherent to the ciliary processes, but also at the optic entrance. This is due to the fact that in the fœtus a blood-vessel, termed the **arteria hyaloidea**, is continued from the arteria centralis retinæ forwards through the vitreous body for the supply of the capsule of the lens. Its position, in the adult, is represented by a lymph channel, termed the **canalis hyaloideus** of Stilling (Fig. 493), the presence of which may be demonstrated by shaking up the vitreous body in a solution of picrocarmine, when some of the pigment may be seen to extend along the canal (Anderson Stuart).

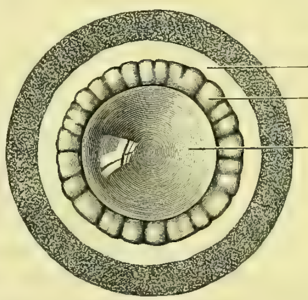


FIG. 503.—CANAL OF PETIT DISTENDED AND VIEWED FROM THE FRONT (enlarged).

When the vitreous body is treated by a weak solution of chromic acid it presents a series of concentric, peripherally-arranged striæ, together with numerous radial striæ converging towards its centre. Between these the more fluid part lies, and it frequently contains vacuolated amœboid cells scattered through it. The vitreous body consists of 98·4 per cent. of water, having in solution about 1·4 per cent. of sodium chloride and traces of extractives and albumen.

The **crystalline lens** (lens crystallina) lies in front of the vitreous body and behind the iris, and is a biconvex, transparent body (Fig. 493). It is enclosed in a thin, transparent, homogeneous capsule, the capsule of the lens (capsula lentis). The central points of its anterior and posterior surfaces are termed respectively its

anterior and posterior poles, a line joining which is known as its **axis** (axis lentis); its peripheral circumference is named the **equator** (æquator lentis). Its axial measurement is 4 mm. and its transverse diameter from 9-10 mm. Its anterior surface (facies anterior lentis) is less curved than the posterior, and its central part corresponds with the aperture of the pupil and is directed towards the anterior chamber. Around the aperture of the pupil the pupillary margin of the iris rests upon the lens, but its peripheral part is separated from it by the aqueous humour of the posterior chamber. Its posterior surface (facies posterior lentis), more convex than the anterior, occupies the fossa patellaris of the vitreous body. The relations of its equator to the suspensory ligament and the canal of Petit have already been referred to. The superficial part of the lens possesses a refractive index of about 1·4 and its central part or nucleus one of about 1·45. The curvatures of its surfaces, especially that of the anterior, are constantly varying during life for the purpose of focussing rays from near or distant objects on the retina.

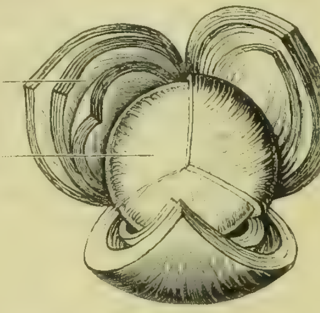


Fig. 504.—Lens hardened in Formalin and dissected to show its Concentric Laminæ (enlarged).

The lens substance (substantia lentis) consists of a soft outer part, the **substantia corticalis**, easily crushed between the finger and thumb, and of a dense central part, the **nucleus lentis**. Faint lines (radii lentis) radiate from its anterior and posterior poles towards its equator. In the fœtus they are three in number and form with each other angles of 120° (Fig. 505). From the anterior pole one ray ascends vertically and the other two diverge downwards, while from the posterior pole one ray descends vertically and the other two diverge upwards. In the adult the rays may be increased to six or more. They represent the free edges of a corresponding number of septa, which dip into the substance of the lens, and along which the extremities of the different groups of lens fibres come into contact and are attached by a clear, amorphous substance. The lens, when hardened, exhibits a series of concentrically-arranged laminæ (Fig. 504), superimposed like the coats of an onion and attached to each other by a clear, amorphous substance. Each lamina is split along the radiating lines and consists of a series of hexagonal, riband-like fibres, the fibræ lentis, which are adherent to each other by their margins; those of the deeper laminæ are smaller and serrated, but non-nucleated; while those of the superficial coats are larger and nucleated, but non-serrated. The fibres extend in a curved manner from the rays on the anterior surface to the rays on the posterior surface, but no fibre extends from pole to pole. Fibres which start at or near one pole end at or near the equator on the opposite surface, and *vice versa*, while the intervening fibres take up intermediate positions. Between the substantia lentis and the anterior part of the capsule there is a layer of nucleated columnar epithelial cells, the epithelium lentis. On being traced towards the equator its cells become gradually elongated and transformed into lens fibres, which, when fully formed, lose all trace of their nuclei, except in the more superficial laminæ. Each lens fibre represents, therefore, a greatly elongated columnar cell (Fig. 506).

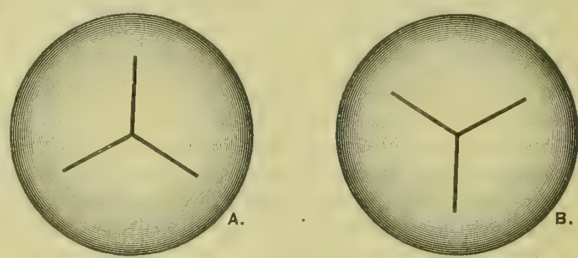


Fig. 505.—Diagrammatic Representation of the Radii Lentis of the Fœtal Lens.
A, Seen from the front; B, From behind.

In the fœtus the lens is soft, of a pinkish colour, and nearly spherical; while in old age it becomes more flattened than in the adult, and, losing its transparency, assumes a yellowish tint.

Chambers of the Eye and Aqueous Humour (Fig. 493).—As already stated (p. 687), the space between the cornea and the lens is divided by the iris into two unequal parts, viz. the anterior chamber in front and the posterior chamber behind. These are filled by the **aqueous humour**, and, in the adult, communicate freely through the aperture of the pupil, but in the fœtus are separated from each other by the pupillary membrane. The **anterior chamber** (camera oculi anterior) is bounded in front by the cornea, behind by the iris and lens, whilst peripherally it communicates with the spaces of Fontana. The **posterior chamber** (camera oculi posterior) is triangular on section, and is bounded in front by the iris, behind by the circumferential part of the lens and its suspensory ligament; the base of the triangle, situated externally, corresponds with the thick, anterior extremities of the ciliary processes. It communicates with the recessus cameræ posterior and canal of Petit. The aqueous humour has a refractive index of about 1·336 and consists of about 98 per cent. of water, with 1·4 per cent. of sodium chloride and traces of albumen.

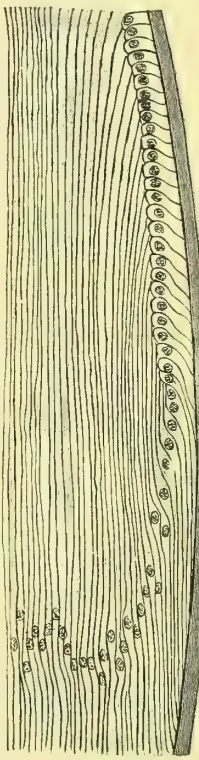


Fig. 506.

Section through the Equator of the Lens. Showing the gradual transition of the epithelium into lens fibres (after Babuchin).

EYELIDS.

The **eyelids or palpebræ** are two movable cutaneous curtains situated in front of the eyeball, and named, from their position, upper and lower. The upper is the larger and more movable, being provided with a special elevator muscle, the m. levator palpebræ superioris. The interval between the lids is termed the **palpebral fissure** (rima palpebrarum), and measures transversely about 30 mm., but varies considerably in different individuals and in different races. When the eye is open the fissure is elliptical in shape, but when closed it assumes the form of a transverse slit, which lies on a level with the lower margin of the cornea. The two lids meet at the extremities of the fissure, and form the **outer** and **inner angles**, or **canthi**. Their free margins are flattened and are surmounted by eyelashes from the external canthus to a point about 5 mm. from the inner canthus—a point indicated by a small papilla, the **papilla lacrimalis**. Internal to this papilla the margins are rounded and destitute of eyelashes, and form the upper and lower boundaries of a triangular space, termed the **lacus lacrimalis**, which is occupied by a small pale-red body, the **caruncula lacrimalis**. This caruncula consists of a minute island of modified skin, and contains sweat glands, sebaceous glands, and fine hairs. Posteriorly, the lids are lined by mucous membrane and are in contact with the eyeball, except near the inner canthus, where, between the eyeball and the caruncula lacrimalis, there intervenes a vertical fold of conjunctiva, the **plica semilunaris conjunctivæ**. This, which in many animals contains a plate of cartilage, is the representative of the membrana nictitans, or third eyelid of birds, etc.

In each lid there exists a framework of condensed fibrous tissue, which gives consistence and shape to the lid, and is termed the **tarsal plate or tarsus**. In front of the tarsus are the fibres of the orbicularis palpebrarum muscle and the integument, while embedded in its posterior surface, and covered by the conjunctiva, are numerous modified sebaceous glands, named the **tarsal or Meibomian glands**. The superior tarsal plate (tarsus superior) is larger than the inferior and of a half oval shape, with its greatest vertical diameter measuring about 10 or 11 mm. Its upper margin is thin and convex, and is continuous with the tendon of the levator palpebræ superioris muscle, while its lower edge is thick and straight. The inferior tarsal plate (tarsus inferior) is a thin, narrow strip, with a nearly uniform vertical diameter of about 5 mm. The extremities of the two plates are continuous with the **external and internal tarsal ligaments**. The external tarsal ligament is a narrow band attached to the malar bone; it divides, at the outer canthus, into

upper and lower pieces, which are fixed to the margins of the respective tarsal plates. The internal tarsal ligament is a strong band attached to the nasal process of the superior maxillary bone directly in front of the lachrymal groove; it divides at the inner canthus into two slips, one for either tarsal plate.

The eyelids are further strengthened by membranous expansions, termed the **superior** and **inferior palpebral ligaments**, which extend into them from the margin of the orbit. The superior ligament is continuous, along the upper margin of the orbit, with the pericranium and with the periosteal lining of the orbit, and blends below with the tendon of the levator palpebræ superioris. The inferior ligament is prolonged from the under edge of the inferior tarsal plate to the lower margin of the orbit, where it is continuous with the periosteum of the face and orbital floor. Externally, the two palpebral ligaments fuse to form the external tarsal ligament, while internally they become thinned, and, separating from the internal tarsal ligament, are attached to the lachrymal bone behind the lachrymal sac. These two palpebral ligaments form a kind of septum or diaphragm, the **septum orbitale,** between the superficial and deep structures of the eyelids; this septum is perforated by the vessels and nerves, which extend from the orbital cavity to the face or scalp.

The skin covering the lids is thin and delicate, and is continuous, at their margins, with their conjunctival lining. It contains numerous small sweat glands and fine hairs, the latter being provided with sebaceous follicles. Branched pigment cells are present in the cutis, and pigment also exists in the deep layers of the epidermis. The subcutaneous tissue is loose and devoid of fat, and in it are found the fibres of the orbicularis palpebrarum muscle—a small separate bundle of which, termed the **muscle of Riolan,** occupies the margin of the lids behind the eyelashes. The **Meibomian glands**, or glandulæ tarsales, are elongated sebaceous glands with numerous lateral offshoots; they are embedded in the tarsal plates and filled with cubical epithelium. Rather more numerous in the upper than in the lower lid, they open by small ducts, about 1 mm. in length, along the lid margins behind the eyelashes; the ducts are lined by stratified epithelium placed on a basement membrane. Between the eyelashes and the muscle of Riolan are two or three rows of modified sweat glands, termed the **glands of Moll,** the blocking of one of the ducts of which frequently gives rise to a stye.

H. Müller described a layer of non-striped muscle in each lid: in the upper extending from the tendon of the levator palpebræ superioris to the upper tarsal plate, and in the lower connecting the inferior tarsal plate with the inferior oblique muscle.

The tendon of the levator palpebræ superioris divides into three parts—an anterior, passing between the bundles of the orbicularis to the deep surface of the skin; a middle, attached to the superior tarsal plate; and a posterior, to the fornix conjunctivæ: there is no corresponding muscle in the lower lid. The eyelashes are curved, silky hairs, which project from the free margins of the lids; in the upper lid they are longer and more numerous than in the lower, and are curved upwards, while those of the lower lid are bent downwards.

Conjunctiva.—This mucous membrane lines the back of the lids (**tunica conjunctiva palpebrarum**) and is continued on to the front of the eyeball (**tunica conjunctiva bulbi**). The line along which it is reflected on to the globe of the eye is termed the **fornix conjunctivæ.** The palpebral portion adheres intimately to the tarsal plate and presents numerous papillæ. It is covered by a layer of columnar epithelial cells, beneath the bases of which are small flattened cells. Near the fornix a number of acino-tubular glands, much more plentiful in the upper than in the lower lid, open on to its free surface. The conjunctiva bulbi is thinner than that lining the lids, and is loosely attached to the sclera by submucous tissue. The plica semilunaris conjunctivæ has already been referred to (p. 695). On the cornea the conjunctiva is represented merely by the stratified epithelium, already described (p. 684).

Vessels and Nerves.—The chief **arteries** of the eyelids are the superior and inferior palpebral branches of the ophthalmic, which pierce the septum orbitale above and below the internal tarsal ligament and run tortuously outwards in the corresponding lid. On reaching the region

of the outer canthus they anastomose with each other and with twigs from the lachrymal, superficial temporal, and transverse facial arteries, and in this way an arch is formed in each lid (upper and lower tarsal arches). Secondary smaller arches are found, one above the primary arch in the upper lid and another below that of the lower lid, while the upper lid also receives branches from the supraorbital and frontal arteries. The **veins** are arranged into two sets: (*a*) subconjunctival or retrotarsal, opening into the muscular tributaries of the ophthalmic vein, and (*b*) pretarsal, which pour their contents into the angular and superficial temporal veins. The **lymphatics**, like the veins, form pre- and retrotarsal networks, which communicate with each other through the tarsal plates. The lymph is drained partly into the preauricular and parotid lymphatic glands, and partly, by vessels which accompany the facial vein, into the submaxillary lymphatic glands. The **sensory nerves** of the eyelids are supplied by the fifth cranial nerve—the upper lid chiefly by the supraorbital and supratrochlear branches of the ophthalmic; the lower, by the infraorbital branch of the superior maxillary. The region of the outer canthus receives some filaments from the lachrymal nerve, that of the inner from the infratrochlear. These sensory nerves form a marginal plexus behind the orbicularis palpebrarum muscle. The levator palpebræ muscle is supplied by the third cranial nerve and the non-striped fibres of the lids by the sympathetic.

LACHRYMAL APPARATUS.

The **lachrymal apparatus** (apparatus lacrimalis) consists of: (1) the lachrymal gland, which secretes the tears; (2) the lachrymal canals, by which they are drained from the front of the globe; and (3) the lachrymal sac and nasal duct, which convey them into the nasal cavity.

The **lachrymal gland** is a flattened, oval body situated in the upper and outer part of the orbital cavity, and consists of two portions—orbital and palpebral—imperfectly separated from each other by the expansion of the tendon of the levator palpebræ superioris muscle. The **orbital** portion, termed the **glandula lacrimalis superior,** is firm and much larger than the palpebral part; it measures transversely about 20 mm., and sagittally from 12-14 mm. It occupies the fossa lacrimalis on the inner aspect of the external angular process of the frontal bone and is fixed by fibrous bands to its periosteum, while its inferior surface is in contact with the levator palpebræ superioris and external recti muscles which intervene between it and the globe of the eye. The smaller, **palpebral portion,** named **glandula lacrimalis inferior,** consists of loosely aggregated lobules. It lies below and in front of the orbital portion and projects into the posterior part of the upper eyelid, where its deep surface is in contact with the conjunctiva. The ducts of the upper gland, from three to five in number, receive those of the lower gland, which vary from three to nine, and open on the upper eyelid close to the fornix conjunctivæ superior. The lachrymal gland has a structure similar to that of the parotid, and is supplied by the sympathetic and lachrymal nerves and by the lachrymal artery, while its veins are drained into the ophthalmic vein.

The **lachrymal canals** (ductus lacrimales) commence by minute orifices, termed the **puncta lacrimalia,** at the apices of the papillæ lacrimales, already referred to (p. 695). The upper canal is the smaller of the two, and at first ascends for a short distance, and then runs inwards and slightly downwards; the lower descends for a short distance and then runs horizontally inwards. At the angle where they change their direction each is dilated into an ampulla (ampulla ductus lacrimalis). They occupy the margins of the lids, where these bound the lacus lacrimalis, and the two canals open close together into the outer and forepart of the lachrymal sac, a little below its middle; sometimes they open separately into a pouch-like dilatation of the sac, termed the sinus of Maier. Each canal is lined by a stratified epithelium placed on a tunica propria, outside which is a layer of striped muscular fibres, derived from the tensor tarsi muscle. These muscular fibres are arranged somewhat spirally around the canals, but at the bases of the papillæ they are circular in direction and form a species of sphincter. On contraction, they serve to empty the contents of the lachrymal canals into the lachrymal sac.

The **lachrymal sac** and **nasal duct** together form the passage by which the tears are conveyed from the lachrymal canals to the nose.

The **lachrymal sac** (saccus lacrimalis) is the upper expanded part of the passage, and measures from 12-15 mm. in length, about 7 mm. antero-posteriorly, and from 4-5 mm. transversely. It lies in the groove formed by the lachrymal bone

and nasal process of the superior maxilla, and ends above in a rounded, blind extremity or fundus, while it narrows below into the nasal duct. Here a fold of mucous membrane, named the valve of Beraud or of Krause, together with a laterally-directed pouch, the sinus of Arlt, are sometimes present. Near its superior extremity it is crossed in front by the internal tarsal ligament, from the upper and lower edges of which the orbicularis palpebrarum takes origin, while behind it is the tensor tarsi muscle, or muscle of Horner.

The **nasal duct** (ductus naso-lacrimalis) averages about 18 mm. in length and has a diameter of from 3-4 mm. Rather narrower near its middle than at its upper and lower extremities, it is directed downwards and slightly backwards, and opens into the inferior meatus of the nose at the junction of its anterior with its posterior three-fourths, *i.e.* a distance of 30-35 mm. from the posterior boundary of the nostril. Its lower orifice is somewhat variable in form and position, and is occasionally duplicated. It is frequently guarded by a fold of mucous membrane, termed the **valve** or **plica lacrimalis of Hasner**. Through this orifice the mucous lining of the duct is continuous with that of the nose. The mucous membrane of the duct is thrown into inconstant folds, several of which have been described as valves. Its epithelium is columnar and in part ciliated; opening into the lower part of the duct are numerous glands, similar to those in the nasal mucous membrane. The nerves of the lachrymal canals and sac are derived from the infratrochlear branch of the nasal; their arteries from the inferior palpebral and nasal. The veins of the nasal duct are large and numerous, forming a sort of erectile tissue similar to that in the nose.

Development of the Eye.

The retina and optic nerve are developed from a hollow outgrowth of the fore-brain, termed the **optic vesicle** (see pp. 442 and 553). This extends towards the side of the head, and its connexion with the brain is gradually elongated to form the **optic stalk**. The ectoderm overlying the optic vesicle becomes thickened, invaginated, and finally cut off as a hollow

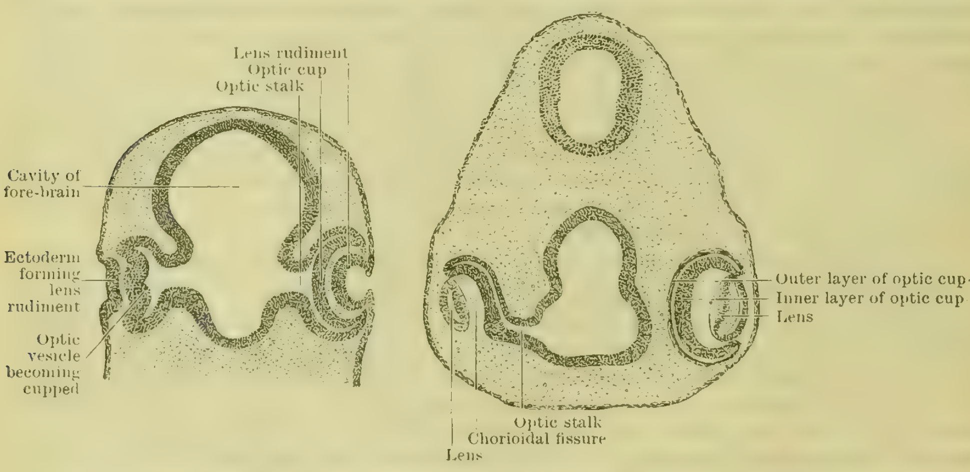


FIG. 507.—SECTIONS THROUGH PORTIONS OF THE HEADS OF FŒTAL RABBITS, to illustrate the connexion of the optic cup with the fore-brain, and the invagination of the ectoderm to form the lens.

island of cells, which is developed into the lens and is named the **lens vesicle**. This lens rudiment indents the outer and lower part of the optic vesicle, which now assumes the form of a cup (**optic cup**), lined by two layers of cells continuous with each other at the margin of the cup. The inner of these strata, thicker than the outer, is named the **retinal layer**, and becomes differentiated into the nervous and supporting elements of the retina; while the outer, named the **pigmentary layer**, forms its pigmented epithelium. The edge of the optic cup extends in front of the equator of the lens, and bounds the future aperture of the pupil. In front of the lens, and also opposite its equator, the retinal layer is thin and represented only by a stratum of columnar cells which becomes closely applied to the pigmentary layer, the two forming the pars ciliaris and pars iridica retinæ. The indentation of the optic cup extends as a groove for some distance along the postero-inferior

aspect of the optic stalk, forming what is termed the **chorioidal fissure** (Fig. 508). Through this fissure the mesoderm passes inwards between the lens and the retina to form the vitreous body, while the arteria centralis retinæ also becomes enclosed in it and so gains its future position in the centre of the optic nerve. The arteria centralis is prolonged forwards from the porus opticus through the vitreous body, as a cone of branches, as far as the back of the lens. By the fifth or sixth month all these branches have disappeared except one, the **arteria hyaloidea**, which persists until the last month of fœtal life, when it also atrophies, leaving only the **canalis hyaloideus** to indicate its position.

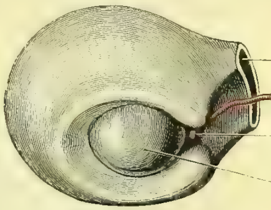


FIG. 508.—OPTIC CUP AND LENS VIEWED FROM BEHIND AND BELOW, to show formation of chorioidal fissure and enclosure of the arteria centralis retinæ (from model by Ziegler).

The lens rudiment, at first in contact with the ectoderm, from which it is derived, soon becomes separated from it by mesoderm, and then consists of a rounded vesicle lined by epithelium. The epithelium which lines the anterior part of the vesicle remains as a single layer of cells—the anterior lens epithelium of the adult. The cells lining the posterior part of the vesicle become elongated into lens fibres, and by the forward growth of these the cavity of the vesicle is obliterated. This elongation into lens fibres is greatest at the centre of the lens, while near the equator the fibres are shorter, and here the gradual transition between the anterior epithelium and the lens fibres is seen (Fig. 506). The lens becomes enveloped in a vascular tunic, which receives its vessels from the arteria centralis retinæ and from the vessels of the iris. The front part of this tunic forms the membrana pupillaris, and this, like the rest of the tunic, disappears before birth.

The hollow stalk of the optic cup becomes solid by the thickening of its walls and the obliteration of its cavity, and, acquiring nerve fibres, becomes the optic nerve. These nerve fibres are mostly centripetal, and are derived from the nerve-cells of the retina; but a few are centrifugal and have their origin in the brain. The further development of the retina resembles, in certain respects, that of the spinal cord. Some of the epithelial cells of the retinal layer become elongated and branched spongioblasts, and are developed into the sustentacular fibres of Müller and their limiting membranes; while others, neuroblasts, give rise to the nervous elements. The rods and cones make their appearance in the human embryo about the end of the fifth month (Falchi), but not until after birth in the cat and rabbit (M. Schultze).

The condensed mesoderm surrounding the optic cup becomes the sclera and chorioid. In the portion of the mesoderm which lies in front of the lens a cleft-like fissure appears, and divides it into a thick anterior and a thin posterior layer. The former becomes the substantia propria of the cornea; the latter, the stroma of the iris and anterior part of the vascular tunic of the lens. The fissure represents the future anterior chamber, and its lining cells form the layer of endothelium on the back of the cornea and front of the iris.

The **eyelids** arise as two integumentary folds above and below the cornea, each being covered on both its surfaces by the ectoderm. By the third month the folds meet and unite with each other at their edges, the eyelids being only permanently opened shortly before birth; in many animals they are not opened until after birth. The ectoderm forms the epithelium of the conjunctiva and the stratified epithelium of the cornea. It is also invaginated at the lid margins to form the hair follicles and the lining cells of the Meibomian glands and glands of Moll, and, at the fornix conjunctivæ, to form the lining of the alveoli and ducts of the lachrymal gland.

The **nasal duct, lachrymal sac, and canals** represent the remains of the furrow which extends from the inner angle of the eye to the nasal cavity between the superior maxillary and lateral nasal processes (p. 38). It is at first filled by a solid rod of cells, which becomes hollowed out to form the duct and canals.

THE EAR.

The ear or organ of hearing (organon auditus, Fig. 509) consists of three portions—external, middle, and internal, the last constituting its essential part, as within it are distributed the peripheral terminations of the auditory nerve.

EXTERNAL EAR.

The **external ear** [1] includes—(*a*) the pinna or auricula, attached to and projecting from the side of the head; and (*b*) the passage or external auditory meatus (meatus acusticus externus), leading inwards from the most depressed part of the pinna as far as the tympanic membrane or outer wall of the middle ear.

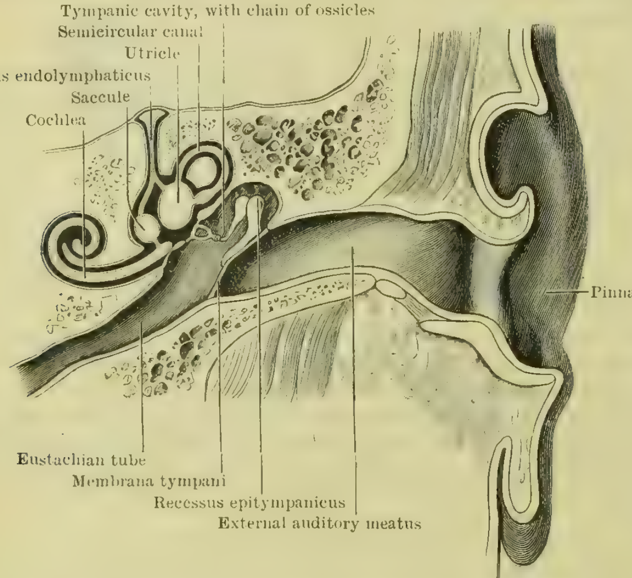


FIG. 509.—DIAGRAMMATIC VIEW OF THE ORGAN OF HEARING.

THE PINNA.

The **pinna or auricula** (Fig. 510) presents two surfaces, outer and inner, the latter forming an angle (cephalo-auricular angle) of about 30°, opening backwards, with the side of the head. The outer surface is irregularly concave, but presents several well-marked elevations and depressions. The deepest of the depressions is situated near its middle, and is named the **concha** (concha auriculæ). It is divided by an almost transverse ridge, the **crus helicis**, into an upper, smaller, and a lower, larger portion: the former is termed the **cymba conchæ**; the latter, which leads into the meatus, the **cavum conchæ**. Anteriorly, the crus helicis is continuous with the margin of the pinna or **helix**, which is folded over, in the greater part of its extent, like the rim of a hat, and is directed at first upwards, and then backwards and downwards, to become gradually lost a little below the middle of the pinna. Where the helix begins to turn downwards a small tubercle, the **tuberculum superius** (Darwini), is often seen; it will be again referred to. In front of the descending part of the helix is a second elevation, the **antihelix**. Single below, this divides superiorly into two limbs, termed the **crura antihelicis**, between which is a triangular depression, the **fossa of the antihelix**, or **fossa triangularis**. The elongated furrow between the helix and antihelix is named the **fossa of the helix** or **scapha**. The concavity of the concha is overlapped in front by a tongue-like process, the **tragus**, and behind by a triangular projection, the **antitragus**. The notch, directed downwards and forwards between these two processes, is named the **incisura intertragica**. The tragus really consists of two tubercles, the upper of which constitutes the **tuberculum supratragicum** of His, and is separated from the helix by a groove, the **sulcus auris anterior**. The **lobule** (lobulus auriculæ) is

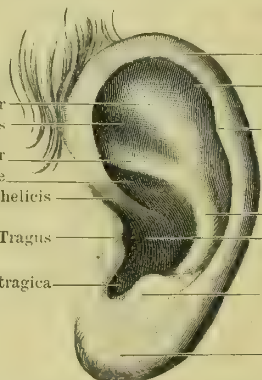


FIG. 510.—VIEW OF OUTER SURFACE OF LEFT PINNA (half natural size).

[1] Although it is usual to speak of the external, middle, and internal ear, it would be more correct to use the terms external, middle, and internal *portions* of the ear.

situated below the incisura intertragica, and is the most dependent part of the pinna.

The inner or cranial surface is also irregular and presents elevations corresponding to the depressions on its outer surface, *e.g.* **eminentia conchæ, eminentia triangularis**, etc.

The pinna is usually smaller and more finely modelled in the female than in the male, but presents great variations in size and shape in different individuals. In the newly-born child its length is about one-third of that of the adult, while it increases slightly in length and breadth in old age.

The relation of the width to the height is termed the auricular index and is expressed as follows:—

$$\frac{\text{width of pinna} \times 100}{\text{length of pinna}} = \textbf{Auricular index.}$$

This index is less in white than in dark races.

The **cephalo-auricular angle** may be practically absent, as in those cases where the skin of the head passes directly on to the outer surface of the pinna, or it may be increased to nearly a right angle, so that the outer surface of the pinna looks directly forwards. The **tuberculum superius**, the significance of which was recognised by Darwin, is a somewhat triangular prominence which projects forwards when the helix is well rolled over, but backwards and upwards when the incurving of the helix has been arrested. More frequently present in men than in women, it is of developmental interest since it has been shown to be well marked at the sixth month of fœtal life, the entire pinna exhibiting, at this stage, the appearance of that of the adult macaque.

The **lobule** may be small and sessile or considerably elongated; it may adhere to the skin of the cheek (webbed) or may tend to bifurcate at its lower extremity.

Structure of the Pinna.—The greater part of the pinna consists of a lamella of yellow fibro-cartilage, the **cartilago auriculæ**; the cartilage is however absent from the lobule, which is composed of adipose tissue. When laid bare, the cartilaginous lamella (Figs. 511, 512) presents, in an exaggerated condition, all the inequalities of the pinna, and is seen to be prolonged inwards, to form a considerable portion of the external auditory meatus. The cartilage of the helix projects anteriorly as a conical eminence, the **spina helicis**, whilst its inferior extremity extends downwards as a tail-like process, the **cauda helicis**, which is separated from the lower part of the antitragus by a fissure, termed the **fissura antitragohelicina**. The cartilage of the pinna is continuous with that of the meatus by a narrow **isthmus** (isthmus cartilaginis auris) measuring from 8-9 mm. in breadth. This isthmus corresponds externally with the deepest part of the incisura intertragica, and internally it forms the outer boundary of a deep fissure, the **incisura terminalis auris**, which separates the cartilage of the meatus from that of the concha. The upper edge of the tragus fits into an angle below the crus helicis.

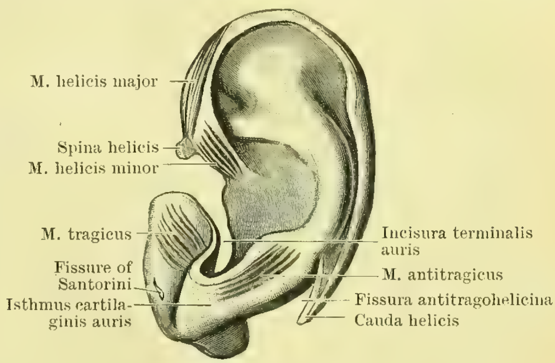


Fig. 511.—Outer Surface of Cartilage of Pinna (one-half natural size).

If the incisura terminalis auris, together with the isthmus and the incisura intertragica, be taken as representing the boundary between the cartilage of the pinna and that of the meatus, it follows that the tragus really forms a part of the meatal cartilage.

On the cranial aspect of the cartilage (Fig. 512) the eminences produced by the concha and fossa triangularis are separated by a transverse furrow, the **sulcus antihelicis transversus**, corresponding with the crus antihelicis inferior; further, the eminentia conchæ is crossed horizontally by a groove, the **sulcus cruris helicis**, and almost vertically by a slight ridge, the **ponticulus**: the latter indicates the attachment of the retrahens auriculam muscle.

In addition to the fissures described, others, termed the **fissures of Santorini**, are found, usually one in the tragus and one or more in the cartilage of the meatus.

Ligaments of the Pinna.—The cartilage of the pinna is attached to the skull by two fibrous bands which form its extrinsic ligaments, viz.: (*a*) *anterior*, stretching from the zygoma to the spina helicis and tragus; and (*b*) *posterior*, passing from the eminentia conchæ and upper wall of the meatus to the mastoid process. Small ligamentous bands pass between individual parts of the pinna, and form what are termed its intrinsic ligaments.

FIG. 512.—INNER SURFACE OF CARTILAGE OF PINNA (one-half natural size).

Muscles of the Pinna (Figs. 511, 512).—The muscles of the pinna are divided into two groups, *extrinsic* and *intrinsic*. The extrinsic muscles pass from the pinna to the skull or scalp, and are described in the section upon Myology. The intrinsic muscles, on the other hand, are confined to the pinna and are six in number, four on its outer and two on its cranial aspect.

(*a*) *On the outer surface* (Fig. 511)—

1. **M. helicis major**, passing upwards from the spina helicis along the ascending part of the helix. 2. **M. helicis minor**, covering the crus helicis. 3. **M. tragicus**, quadrangular in shape, and consisting of fibres running vertically over the greater part of the tragus. Some of its fibres are prolonged upwards to the spina helicis and constitute the m. pyramidalis. 4. **M. antitragicus**, covering the antitragus and passing obliquely upwards and backwards as far as the antihelix and cauda helicis.

(*b*) *On the cranial surface* (Fig. 512)—

1. **M. transversus auriculæ**, consisting of scattered fibres, which stretch from the eminentia conchæ to the convexity of the helix. 2. **M. obliquus auriculæ** (Tod), comprising a few fasciculi, which run obliquely or vertically across the furrow corresponding with the crus antihelicis inferior. A small muscle, the stylo-auricularis, sometimes extends from the root of the styloid process to the cartilage of the meatus.

Skin of the Pinna.—The skin covering the pinna is thin and smooth, and is prolonged inwards, in the form of a tube, as a lining to the external auditory meatus. It adheres firmly, on the outer surface of the pinna, to the subjacent perichondrium. Hairs are well developed on the tragus and antitragus, and also in the incisura intertragica, forming the **barbula hirci**, which guard the entrance to the concha. Soft downy hairs are found over the greater part of the pinna and point towards Darwin's tubercle. Sebaceous glands, present on both surfaces of the pinna, are most numerous in the concha and fossa triangularis. Sweat glands are found on both surfaces, but are much more numerous on the cranial aspect.

Vessels of the Pinna.—The **arteries** for the pinna are derived—(*a*) from the superficial temporal, which sends two or three branches to the outer surface; and (*b*) from the posterior auricular, which gives three or four branches to the cranial surface. From the latter, two sets of twigs are prolonged to the outer surface, one turning round the free margin of the helix and the other passing through small fissures in the cartilage. The **veins** from the outer surface open into the superficial temporal vein; those from the cranial surface chiefly join the posterior auricular vein, but some communicate with the mastoid emissary vein. The **lymphatics** take three directions, viz.: (*a*) forwards to the preauricular gland in front of the tragus, (*b*) downwards to the parotid lymphatic glands, and (*c*) backwards to the highest of the mastoid lymphatic glands.

Nerves of the Pinna.—The muscles of the pinna are supplied by the seventh cranial nerve. The skin receives its sensory nerves from—(*a*) the great auricular, which supplies nearly the whole of the cranial surface and sends filaments in company with the branches of the posterior auricular artery to the outer surface; (*b*) the auriculo-temporal, which supplies the tragus and ascending part of the helix; (*c*) the small occipital, which sends a branch to the upper part of the cranial surface.

EXTERNAL AUDITORY MEATUS.

The **external auditory meatus** (meatus acusticus externus) (Figs. 513, 514) is the passage leading inwards from the concha as far as the membrana tympani. Its

average length, measured from the bottom of the concha, is about one inch (24 mm.), but, if measured from the level of the tragus, nearly one inch and a half (35 mm.). Its anterior and inferior walls are longer than the posterior and superior. The tube consists of two parts, viz.: (*a*) an external **fibro-cartilaginous portion**, the pars cartilaginea, having a length of about 8 mm.; and (*b*) an internal **osseous portion,** the pars ossea, measuring about 16 mm., and formed by a portion of the temporal bone. The entire meatus forms a somewhat S-shaped bend (Fig. 514) and may be divided into three portions, viz.: (1) **pars externa**, directed inwards, forwards, and slightly upwards for about 7 mm.; (2) **pars media**, inclining inwards and backwards for about 5 mm.; (3) **pars interna**, the longest of the three, passing forwards, inwards, and slightly downwards. On transverse section the canal is seen to be elliptical, its greatest diameter having an inclination downwards and backwards. Widest at its outer extremity, it becomes somewhat narrower at the inner end of the pars cartilaginea; once more expanding in the outer part of the pars ossea, it is again constricted near the inner end of the latter, where its narrowest part, or **isthmus**, is found at a distance of about 19 mm. from the bottom of the concha. The inner extremity of the meatus is nearly circular and is closed by the membrana tympani.

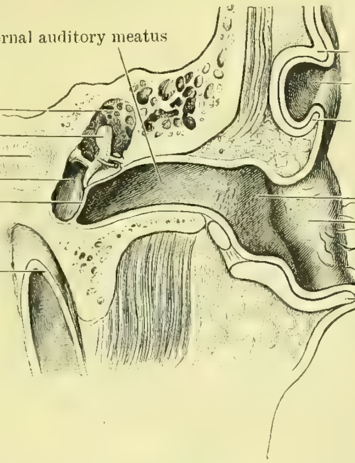


FIG. 513.—VERTICAL TRANSVERSE SECTION OF RIGHT EAR; ANTERIOR HALF OF SECTION, viewed from behind (natural size).

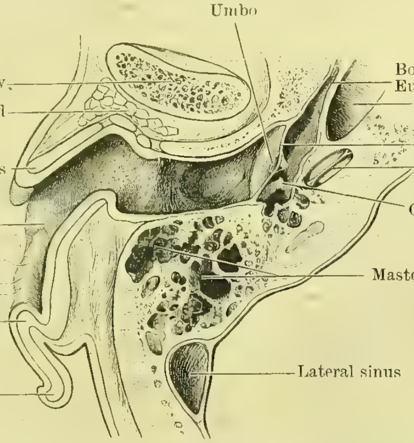


FIG. 514.—HORIZONTAL SECTION THROUGH RIGHT EAR; UPPER HALF OF SECTION, seen from below (natural size).

The lumen of the pars cartilaginea is influenced by the movements of the lower jaw, being increased when it is depressed. This can be easily verified by inserting a finger into the meatus, and then alternately opening and shutting the mouth.

The condyle of the jaw lies in front of the pars ossea, while between the jaw and the pars cartilaginea there intervenes a portion of the parotid gland. Below the meatus is the retro-mandibular part of the parotid gland. Behind the pars ossea, and separated from it by a thin plate of bone, are the mastoid air-cells.

Structure of the Meatus.—The cartilage of the meatus, directly continuous with that of the pinna, is folded on itself to form a groove, opening upwards and backwards, the margins of which are connected by fibrous tissue. The inner end of the cartilage is firmly fixed to the outer margin of the bony meatus, whilst its outer extremity is continuous with the cartilage of the tragus (*vide* p. 701). A couple of fissures, the **fissures of Santorini,** exist in the anterior portion of the cartilage of the

meatus, and are filled by fibrous tissue. In the outer part of the meatus, the cartilage forms about three-fourths of its circumference; but, on passing inwards, the proportion of cartilage to fibrous tissue diminishes, with the result that near the inner end of the pars cartilaginea the cartilage forms merely a part of the anterior and lower boundaries of the canal.

The osseous portion (pars ossea) of the meatus is described on p. 113; but it may be well to state here that in the newly-born child it is represented only by an incomplete ring of bone, the **annulus tympanicus**, together with a small portion of the squamous temporal, which articulates with, and bridges over the interval between, the extremities of the ring superiorly. In the concavity of the annulus is a well-defined groove, the **sulcus tympanicus**, in which the circumference of the membrana tympani is fixed. A fibrous plate, the **tympanic fibrous plate** (Symington), intervenes between the annulus tympanicus and the inner end of the cartilage of the meatus, and into this plate the bony ring extends. The bony outgrowth does not, however, proceed uniformly throughout its circumference, but occurs most rapidly in the anterior and posterior parts of the ring. These outgrowths fuse about the end of the second year of life, so as to surround a foramen in the floor of the meatus (**foramen of Huschke**), which is usually closed by the fifteenth year, but persists until adult life in some 19 per cent. of skulls.

The lumen of the meatus in the newly-born child is extremely small: its outer part is funnel-shaped; its inner a mere slit, bounded below by the tympanic fibrous plate and above by the obliquely-placed membrana tympani.

The **skin** which envelopes the pinna lines the entire meatus, and covers also the outer surface of the tympanic membrane. It is thick in the pars cartilaginea and contains fine hairs and sebaceous glands, the latter extending inwards for some distance along the postero-superior wall of the pars ossea. The sweat glands are enlarged and of a brownish colour; they constitute the **glandulæ ceruminosæ** and secrete the ear wax or cerumen.

Vascular and Nervous Supply of the Meatus.—The meatus receives its blood-supply from the posterior auricular and superficial temporal arteries, and also from the deep auricular branch of the internal maxillary artery, the last distributing some minute branches to the membrana tympani. The **veins** open into the external jugular and internal maxillary veins, and also into the pterygoid plexus, while the **lymphatics** have a similar mode of termination to those of the pinna. **Sensory nerves** are supplied to the meatus by the auriculo-temporal branch of the fifth and by the auricular branch of the vagus.

MIDDLE EAR OR TYMPANIC CAVITY.

The **tympanic cavity** (cavum tympani) is a small air chamber in the temporal bone, intervening between the inner end of the external auditory meatus and the outer wall of the internal ear or labyrinth (Figs. 513, 514). Lined by mucous membrane, it contains a chain of ossicles (ossicula auditus), which reaches from its outer to its inner wall, and by means of which the vibrations of the membrana tympani are transmitted across the cavity to the internal ear. Attached to the ossicles are several ligaments, together with a pair of small muscles, while certain nerves are either distributed to the cavity or pass through it.

The tympanic cavity consists of two portions: (1) The **tympanum proper,** or **atrium**, lying immediately to the inner aspect of the membrana tympani; and (2) the **recessus epitympanicus**, or **aditus ad antrum,** lying above the level of the membrane and containing the greater part of the incus and the upper half of the malleus. Including this recess, the vertical and antero-posterior diameters of the tympanic cavity are rather more than half an inch (15 mm.). The distance between its outer and inner walls is about 6 mm. above and 4 mm. below, while at its central part, owing to the bulging of the two walls towards the cavity, it measures only from $1\frac{1}{2}$ to 2 mm.

The tympanic cavity presents for examination a roof, a floor, and four walls, viz. anterior, posterior, external, and internal.

The **roof** (Fig. 515) (paries tegmentalis) is formed by a thin plate of bone, the **tegmen tympani**, constituting a portion of the upper surface of the petrous-temporal. It extends backwards so as to cover in the mastoid antrum, and forwards, to form the roof of the canal for the tensor tympani muscle. It separates the tympanum and antrum from the cranial cavity and may contain a few air-cells, whilst occasionally it is partly deficient. In the child, its outer edge corresponds with the petro-

squamous suture. The **floor** (fundus tympani seu paries jugularis) is narrower than the roof and consists of a thin plate of bone, which separates the cavity from the fossa jugularis; anteriorly, it extends upwards and becomes continuous with the

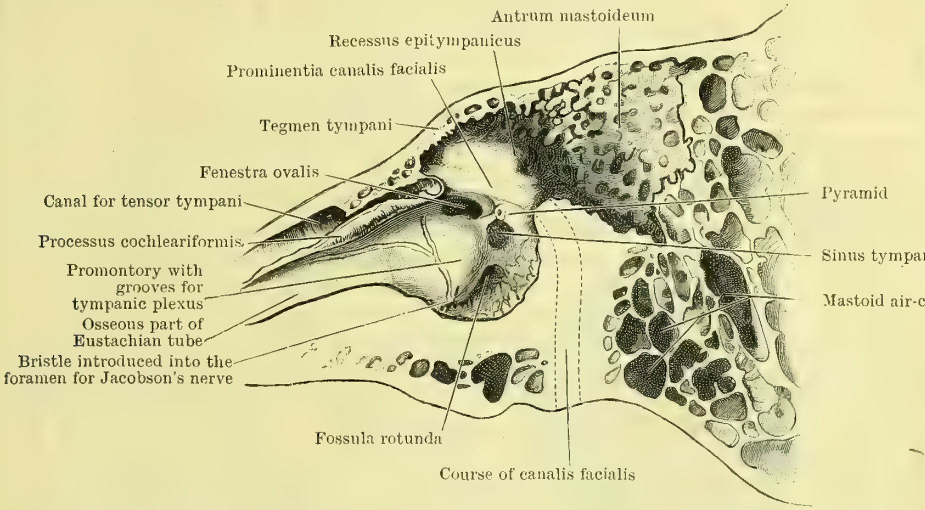


Fig. 515.—Section through Left Temporal Bone, showing inner wall of tympanic cavity, etc.

posterior wall of the carotid canal. The inner orifice for Jacobson's nerve, or tympanic branch of the glosso-pharyngeal, is seen near the junction of the floor with the inner wall.

The **posterior wall** (paries mastoidea) presents, from above downwards: (1) A rounded or triangular opening, which extends backwards from the recessus epitympanicus and leads into the **mastoid antrum** (Fig. 515). The mastoid antrum will be again referred to (p. 708). (2) A depression, the **fossa incudis** (Fig. 516), for the lodgment of the short process of the incus; this fossa is situated in the postero-inferior part of the recessus epitympanicus. (3) A minute conical bony projection, the **pyramid** or eminentia pyramidalis (Fig. 515), the summit of which is perforated by a round aperture for the passage of the tendon of the stapedius muscle. This aperture is continued downwards and backwards as a canal in front of the Fallopian aqueduct, and opens, by a minute orifice, on the base of the skull in front of the stylo-mastoid foramen. It communicates with the Fallopian aqueduct by one or two small foramina, through which the vessels and nerve pass to reach the stapedius muscle. A minute spicule of bone often extends from the pyramid to the promontory on the inner wall of the tympanum. (4) A small aperture, the **apertura tympanica canaliculi chordæ** (Fig. 516); this is situated immediately internal to the posterior edge of the membrana tympani, nearly on a level with the upper end of the manubrium mallei. (5) A rounded eminence, the **prominentia styloidea**, is sometimes

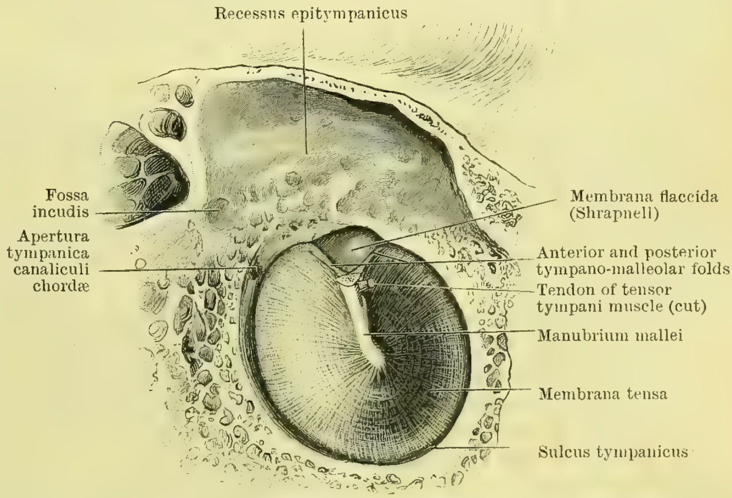


Fig. 516.—Left Membrana Tympani and Recessus Epitympanicus, viewed from within. The head and neck of the malleus have been removed to show the membrana flaccida and the tympano-malleolar folds. × 3.

seen below the last; it is caused by the upward and forward prolongation of the styloid process.

The **anterior wall** (paries carotica) is narrowed in its transverse diameter by the approximation of the outer and inner boundaries of the cavity, and in its vertical diameter by the descent of the roof and ascent of the floor. It presents (Fig. 515) two parallel canals, one above the other, separated by a thin lamella of bone, the **processus cochleariformis** (septum canalis musculo-tubarii). The higher and smaller of the two is termed the **canal for the tensor tympani muscle** (semicanalis m. tensoris tympani) and lies immediately below the tegmen tympani. It has a diameter of about 2 mm. and extends on to the inner wall of the tympanic cavity. The lower and larger canal gradually increases in size from before backwards, and forms the **bony part of the Eustachian tube** (semicanalis tubæ auditivæ). It opens on the anterior wall of the tympanic cavity opposite the orifice leading into the mastoid antrum. The Eustachian tube is described on p. 708.

The **outer wall** (paries membranacea) is formed almost entirely by the membrana tympani, which closes the inner extremity of the external auditory meatus (Fig. 516) and is fixed, throughout the greater part of its circumference, in a groove, the **sulcus tympanicus**. The bony ring containing this sulcus is deficient superiorly where it exhibits a distinct notch, the **notch of Rivinus**. On a level with the upper edge of the membrane, and in front of the ring of bone in which it is fixed, is the inner end of the **Glaserian fissure**, or remnant of the **fissura petro-tympanica**. This transmits the tympanic branch of the internal maxillary artery and lodges the processus gracilis and anterior ligament of the malleus. Close to the inner extremity of the fissure is the **canal of Huguier**, or **iter chordæ anterius**, through which the chorda tympani nerve leaves the tympanum.

Membrana Tympani.—This is an elliptical disc, its greatest diameter, 9 to 10 mm., being directed from above and behind, downwards and forwards, whilst its least diameter is from 8 to 9 mm. Its antero-inferior portion inclines markedly inwards, and thus the membrane is placed very obliquely, forming an angle of about 55° with the lower and anterior walls of the external auditory meatus; its antero-inferior part is, therefore, most distant from the outer orifice of the meatus. The membrane is said to be more oblique in cretins and deaf mutes, and more perpendicular in musicians.

The circumference of that portion of the membrane which is fixed in the sulcus tympanicus is considerably thickened, and is named the **annulus fibro-cartilagineus.** It is prolonged from the anterior and posterior extremities of the notch of Rivinus to the short process of the malleus in the form of two ligamentous bands, the **anterior** and **posterior malleolar folds** or **ligaments** (plica malleolaris anterior et posterior). The small triangular portion of the membrane (Fig. 516), situated above these folds, is thin and lax, and constitutes the **pars flaccida** or membrane of Shrapnell; the main portion of the membrane is, on the other hand, tightly stretched and termed the **pars tensa.** A small orifice, sometimes seen in the pars flaccida, is probably either a pathological condition or has been artificially produced during manipulation. The handle of the malleus is firmly fixed to the inner surface of the membrana tympani and draws its central portion inwards, rendering its outer aspect concave. The deepest part of this concavity corresponds with the lower extremity of the handle of the malleus, and is named the **umbo membranæ tympanæ** or **navel.**

The membrana tympani consists of three layers: (1) external, integumentary (stratum cutaneum); (2) middle, fibrous (membrana propria); (3) internal, mucous (stratum mucosum).

The **external layer** (stratum cutaneum) is continuous with the integumentary lining of the meatus and consists of a thin layer of cutis, covered by epidermis. The cutis is thickest near the circumference; the epidermis, on the other hand, is thickest near the centre of the membrane.

The **middle layer** (membrana propria) consists of two sets of fibres: (*a*) *external* or *radial* (stratum radiatum), immediately under the integument, and radiating outwards from the handle of the malleus to the annulus fibro-cartilagineus; (*b*) *internal* or *circular* (stratum circulare), the fibres of which are numerous

near the circumference, but scattered and few in number near the centre of the membrane (Fig. 516). Both radial and circular fibres are absent from the pars flaccida, which is constituted merely by the apposition of the cutaneous and mucous layers. Gruber pointed out that, in addition to the radial and circular fibres, there exists a series of *dendritic* or *branched fibres*, which are best developed in the posterior part of the membrane.

The **internal layer** (stratum mucosum) is continuous with the general mucous lining of the tympanum. It is thicker over the upper part of the membrane than near its centre and is covered by pavement epithelium.

Otoscopic Examination of the Tympanic Membrane (Fig. 517).—The membrane, in the living, is of a "pearl-gray" colour, but may present a reddish or yellowish tinge, depending upon the condition of its mucous lining and on the condition of the cutaneous lining of the meatus; the posterior segment is usually clearer than the anterior. At the antero-superior part, close to its periphery, a whitish point appears as if projecting towards the meatus; this is the short process of the malleus. Passing downwards and backwards from this point to the umbo is a ridge caused by the handle of the malleus, the lower extremity of which appears rounded. Two ridges, corresponding with the tympano-malleolar folds, extend from the short process of the malleus, one forwards and upwards, the other backwards and upwards. Behind, and near the lower extremity of the handle of the malleus, is a reddish or yellowish spot, due to the promontory of the inner tympanic wall shining through. If the membrane be very transparent, the long process of the incus may be visible behind the upper part of the handle of the malleus, and reaching downwards as far as its middle. From the lower end of the handle of the malleus, the "cone of light" or "luminous triangle" extends downwards and forwards, its apex being directed towards the handle; this triangle varies in size in different people. A line prolonging the handle downwards divides the membrane into two parts, while another, drawn at right angles to this through the umbo, will subdivide it into four quadrants, viz. postero-superior, postero-inferior, antero-superior, and antero-inferior; this subdivision is useful in enabling the otologist to localise and describe accurately the seat of lesions in the membrane.

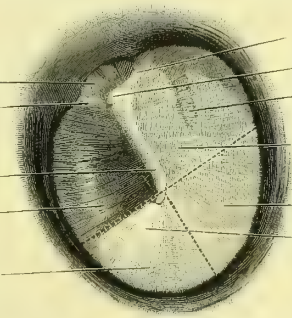


Fig. 517.—Left Tympanic Membrane (as viewed from the external auditory meatus). × 3.

Vascular and Nervous Supply of the Membrana Tympani.—The **arteries** are arranged in two sets, one on the cutaneous and another on the mucous surface. These anastomose by means of small branches which pierce the membrane, especially near its periphery. The first set is chiefly derived from the deep auricular branch of the internal maxillary, whilst those on the mucous surface are small and proceed from the tympanic branch of the internal maxillary, and from the stylo-mastoid branch of the posterior auricular. The **veins** from the cutaneous surface open into the external jugular; those from the inner surface partly into the venous plexus on the Eustachian tube, and partly into the lateral sinus and veins of the dura mater. The outer surface of the membrane receives its **nerves** from the auriculo-temporal branch of the fifth and from the auricular branch of the vagus; the inner surface, from the nerve of Jacobson (tympanic branch of the glosso-pharyngeal). The **lymphatics**, like the blood-vessels, are arranged in two sets, cutaneous and mucous, which, however, communicate freely with each other. Kessel has described as lymphatics the spaces between the branches of Gruber's dendritic fibres.

The **inner wall** of the tympanic cavity (paries labyrinthica) is formed by the outer surface of the internal ear or labyrinth (Fig. 515). It presents—(1) a rounded eminence, the **promontory** (promontorium), which is caused by the first coil of the cochlea, and is grooved for the tympanic plexus of nerves. (2) An oval or somewhat reniform opening, the **fenestra ovalis seu vestibuli.** This is situated above and behind the promontory, and its long axis is directed from before backwards. It measures 3 mm. in length and $1\frac{1}{2}$ mm. from above downwards, and lies at the bottom of a funnel-shaped recess, the **fossula fenestræ vestibuli.** In the macerated bone it leads into the vestibule of the labyrinth, but is closed in the recent state by the foot of the stapes, surrounded by its **ligamentum annulare.** (3) An elevation, the **prominentia canalis facialis.** Situated above the fenestra ovalis, in the recessus epitympanicus, this indicates the position of the **aqueduct of Fallopius**, which contains the facial nerve and is continued backwards and downwards behind the

tympanic cavity, to end at the stylo-mastoid foramen. (4) The **processus cochleariformis**, or septum canalis musculo-tubarii. This process extends backwards, above the anterior end of the fenestra ovalis, where it makes a sharp outward curve and forms a pulley, over which the tendon of the tensor tympani muscle plays. (5) A funnel-shaped recess, the **fossula fenestræ cochleæ**, which is situated behind and below the promontory and almost hidden by its overhanging edge. It leads forwards, upwards, and inwards to an irregularly-oval opening, termed the **fenestra rotunda seu cochleæ**, which in the macerated bone communicates with the cochlea, but in the recent state is closed by a membrane, the **membrana tympani secundaria**. This membrane appears angularly bent along a line joining its antero-inferior two-thirds with the postero-superior third. It consists of three layers: (*a*) *external*, continuous with the mucous lining of the tympanum and containing a network of capillaries; (*b*) *middle*, or substantia propria, the fibres of which radiate chiefly towards the periphery of the membrane—some branched, dendritic fibres are also present; (*c*) *internal*, continuous with the epithelial lining of the labyrinth. (6) Between the fenestra ovalis above and the fossula rotunda below is a small circular depression, the **sinus tympani**, perforated by one or two minute foramina for blood-vessels, whilst immediately internal to it is the ampullated extremity of the posterior semicircular canal.

Mastoid Antrum and Mastoid Air-cells.

The **mastoid antrum** (antrum mastoideum seu tympanicum) is seen in the temporal bone at birth as a cavity, having a vertical measurement of 7-9 mm. and a transverse of 9-11 mm., and is nearly as large in the newly-born child as in the adult. Roofed in by the tegmen tympani, its floor and inner wall are formed by the petro-mastoid, while externally it is closed by the junction of the thin outer part of the squama with the pars mastoidea. At birth its outer wall has a thickness of only 1-2 mm., but by the ninth year this has increased to about 10 mm. Coincident with the growth of the mastoid process the mastoid air-cells are developed downwards and backwards as diverticula from the antrum, and present the greatest possible variations in different skulls. They may be large, comparatively few in number, and involve the whole process, in which case the compact bone which surrounds them is extremely thin and the innermost cells are only separated by a transparent lamella from the lateral sinus. In other cases the cells may be small and numerous, only invading a portion of the process, the remainder consisting of diploëtic tissue. No definite conclusion can be come to as to their condition by external percussion or examination. A solid process is occasionally seen. The air-cells are not limited to the mastoid process, but extend forwards over the roof of the meatus, upwards towards the squama, and inwards towards the temporo-occipital suture, whilst in a few cases they are seen to invade the pars jugularis of the occipital bone. They are lined by thin mucous membrane continuous with that of the tympanum; the deep surface of the mucous membrane is firmly fixed to the periosteum, while its free surface is covered by a layer of flattened, non-ciliated epithelium.

Eustachian Tube.

The **Eustachian tube** (tuba auditiva Eustachii) leads from the tympanic cavity to the naso-pharynx and transmits air to the former, in order that the pressure on the inner and outer surfaces of the membrana tympani may be equalised; it may also serve to convey mucous secretion away from the tympanic cavity. Its outer extremity, the **ostium tympanicum tubæ auditivæ** (Fig. 515), opens into the anterior part of the tympanic cavity below the canal for the tensor tympani muscle. Directed downwards and inwards, the tube ends on the upper part of the naso-pharynx by a wide orifice, the **ostium pharyngeum tubæ auditivæ** (Fig. 490). It measures about an inch and a half (36 mm.) in length, and forms with the horizontal plane an angle of 30° to 40°, with the sagittal plane an angle of about 45°, and with the bony part of the external meatus one of 135° to 140°. It consists of two portions: (*a*) an antero-internal, fibro-cartilaginous part, the **pars cartilaginea tubæ**

auditivæ, having a length of about one inch; and (*b*) a postero-external, osseous part, the **pars ossea tubæ auditivæ,** measuring half an inch in length. The two portions are not in the same plane, the cartilaginous part inclining downwards a little more than the osseous portion and forming, with it, a wide angle. Its lumen is widest at the ostium pharyngeum, narrowest at the junction of the bony and cartilaginous portions, forming here the **isthmus**, and again expanding towards the tympanic cavity; hence it presents, on longitudinal section, somewhat the appearance of an hour-glass. The pars ossea occupies the angle between the squamous and petrous parts of the temporal bone, and is separated by the processus cochleariformis from the canal containing the tensor tympani muscle, whilst immediately to its inner side is the carotid canal. The pars cartilaginea consists partly of cartilage and partly of fibrous membrane. The cartilage (cartilago tubæ auditivæ) presents the form of an elongated triangular plate, of which the apex is firmly attached to the inner end of the pars ossea, while the base is free and forms a projection on the upper and posterior aspects of the pharyngeal orifice. The upper edge of this cartilaginous plate is bent outwards in the form of a hook, and so produces a furrow open below and externally, the furrow being converted into a complete canal by the fibrous part of the tube. On transverse section (Fig. 518) the cartilage presents two laminæ, continuous with each other superiorly: (*a*) *lamina medialis,* broad and thick; and (*b*) *lamina lateralis,* thin and hook-shaped. At the ostium pharyngeum the lamina medialis forms the entire inner wall of the tube, but it gradually diminishes in breadth on approaching the isthmus tubæ. Fissures are often seen in the cartilage; sometimes it is completely separated into several pieces, or accessory islands may be observed in the roof, floor, or membranous part.

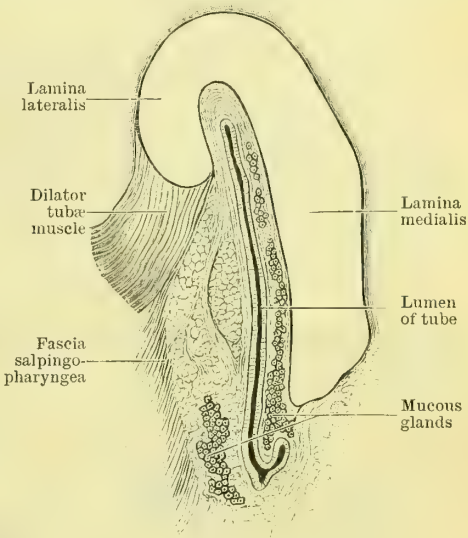


FIG. 518.—TRANSVERSE SECTION OF THE CARTILAGINOUS PART OF THE EUSTACHIAN TUBE.

The upper and inner aspects of the cartilage are firmly fixed to the base of the skull, where it lies in a groove, the **sulcus tubæ auditivæ**, situated between the great wing of the sphenoid and the petrous-temporal. Extending forwards on to the root of the pterygoid process this sulcus ends at a projection, the **processus tubarius**, on the middle of the internal pterygoid plate. The tensor palati muscle lies to the outer side of the tube and receives some fibres of origin from its lamina lateralis; these fibres constitute the **dilator tubæ muscle** of Rüdinger. To the inner side of the cartilage are found the levator palati and the mucous membrane of the pharynx. The **membranous part** (lamina membranacea) consists of a strong fibrous membrane, stretching between the two edges of the cartilage, and so completing the under and outer parts of the canal. Thin above, it becomes thickened below and forms the **fascia salpingo-pharyngea** of Tröltsch, which gives origin to some of the fibres of the tensor palati muscle. Between this fascia and the mucous lining of the tube is a layer of adipose tissue.

The **pharyngeal orifice** of the Eustachian tube (ostium pharyngeum tubæ), triangular or oval in shape, is situated on the lateral wall of the naso-pharynx, the centre of the opening being on a level with the posterior end of the inferior turbinated bone. It is bounded above and behind by a pad or cushion produced by the inner end of the cartilage, which here abuts against the mucous membrane. The posterior part of this cushion is very prominent and forms the anterior boundary of the **fossa of Rosenmüller.** Prolonged downwards from it is an elevation of the mucous membrane, termed the **plica salpingo-pharyngea**, which covers the small salpingo-pharyngeus muscle. From the upper part of the cushion an indistinct fold, the **plica salpingo-palatina**, extends to the palate.

The mucous lining of the tube is continuous behind with that of the tympanic cavity and in front with that of the naso-pharynx. It is thin in the pars ossea, contains few, if any, mucous glands, and is firmly fixed to the bony wall; whilst in the pars cartilaginea it is loose and thrown into longitudinal folds. Numerous mucous glands open into the tube near its pharyngeal orifice, and here also there exists a considerable amount of adenoid tissue, which constitutes the "tube-tonsil" of Gerlach. This adenoid tissue is continuous with that of the naso-pharynx, and, like it, is especially well developed in children. The lumen of the tube is lined with ciliated columnar epithelium.

The tube is opened, during deglutition, by the dilator tubæ and salpingo-pharyngeus muscles. The former springs superiorly from the cartilaginous hook of the tube, and blends inferiorly with the tensor palati. When the dilator tubæ contracts, the cartilaginous hook and membranous part of the tube are drawn outwards and forwards. Some anatomists are inclined to the view that the entire tensor palati acts chiefly as a dilator of the tube, and Rüdinger has named it the abductor tubæ. The salpingo-pharyngeus muscle draws downwards and backwards the inner cartilaginous plate, increasing the angle between it and the outer plate. Some difference of opinion exists as to the precise action of the levator palati; probably it assists in opening the tube.

The Eustachian tube receives its blood-supply from the ascending pharyngeal artery and from the middle meningeal and Vidian branches of the internal maxillary artery. Its veins form a network which opens into the pterygoid venous plexus. The sensory nerves of the tube are derived from the tympanic plexus and from the pharyngeal branches of the second division of the fifth cranial nerve.

The tube of the child differs considerably from that of the adult; its lumen is relatively wider, its direction more horizontal, and its pars ossea relatively shorter. Kunkel states that its pharyngeal orifice is below the level of the hard palate in the fœtus; at birth it is on the same level as the palate, whilst at the fourth year it is 3 to 4 mm., and in the adult 10 mm., above it. The pharyngeal orifice forms a narrow fissure and its cartilage projects less towards the middle line.

Tympanic Ossicles.

The **tympanic ossicles** (ossicula auditus) form an articulated column connecting the outer with the inner wall of the tympanic cavity, and are named, from

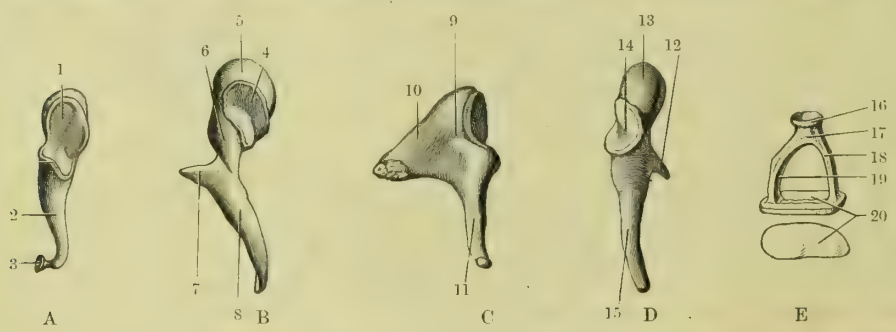


Fig. 519.—Tympanic Ossicles of Left Ear (enlarged about three times).

A, Incus, seen from the front; B, Malleus, viewed from behind; C, Incus, and D, Malleus, seen from inner aspect; E, Stapes.

1. Body of incus, with articular surface for head of malleus.
2. Processus longus.
3. Processus lenticularis.
4. Articular surface for incus.
5. Head.
6. Neck.
7. Processus brevis.
8. Manubrium.
9. Body.
10. Short process.
11. Long process.
12. Processus longus.
13. Head.
14. Facet for incus.
15. Manubrium.
16. Head.
17. Neck.
18. Crus anterior.
19. Crus posterior.
20. Footplate.

without inwards, the malleus or hammer, the incus or anvil, and the stapes or stirrup. The first is attached to the inner surface of the membrana tympani; the last is fixed within the circumference of the oval fenestra.

The **malleus** (Fig. 519, B, D), the largest of the three ossicles, has a length of 8 to 9 mm., and consists of a head (capitulum mallei), a neck (collum mallei), and a handle (manubrium mallei), together with two processes, viz.: (*a*) processus longus

seu anterior, (*b*) processus brevis seu lateralis. The head and neck are situated in the epitympanic recess; the processus brevis and manubrium are fixed to the inner surface of the membrana tympani; whilst the processus longus is directed forwards

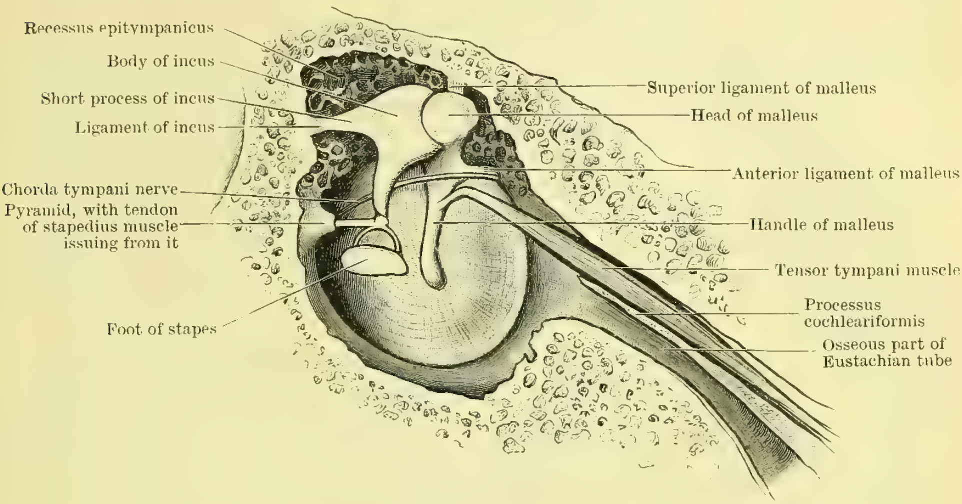


FIG. 520.—LEFT MEMBRANA TYMPANI AND CHAIN OF TYMPANIC OSSICLES (seen from inner aspect). × 3.

towards the Glaserian fissure, to which, in the adult, it is connected by ligamentous fibres. The **head**, somewhat rounded, is smooth and convex above and in front, and presents, on its posterior aspect, a facet for articulation with the body of the incus. This facet is directed obliquely downwards and inwards, and reaches slightly on to its mesial surface. More or less elliptical in form, it is constricted near the middle so as to resemble, somewhat, a figure of 8: an oblique ridge, corresponding with the constriction, divides the facet into two parts—an upper and larger, directed backwards; and a lower and lesser, directed inwards. Opposite the lower part of the constriction the inferior edge of the facet is very prominent, and is continued upwards into the oblique ridge, just referred to; it forms a tooth-like process, the **spur** or **cog-tooth** of the malleus. On the back of the head, below this spur, is an oblique crest, the **crista mallei**, to which is attached the posterior ligament of the malleus. The **neck** is the slightly-constricted portion immediately below the head. Flattened from before backwards, its outer surface is directed towards the membrana flaccida, whilst its inner is crossed by the chorda tympani nerve. The **handle** is directed downwards, inwards, and backwards from the neck, forming with the long axis of the head an angle, opening inwards, of 126° to 150°. Its upper part is flattened from before backwards, but towards the lower end it is twisted on itself, so that its surfaces look outwards and inwards; moreover, the lower end is slightly curved, the concavity being directed forwards and outwards. It is fixed, along its entire length, to the membrana propria of the tympanic membrane by its periosteum and by a layer of cartilage (Gruber). This latter intervenes between the handle and the membrane, and must be regarded as a residue of that stage of development when the entire malleus was cartilaginous. On the inner aspect of the handle, near its upper extremity, a slight projection for the attachment of the tendon of the tensor tympani muscle may be seen. The **long process** is a slender spicule springing from the forepart of the neck and directed forwards towards the Glaserian fissure. In the fœtus it constitutes the longest process of the malleus and is directly continuous with Meckel's cartilage. In the adult it usually assumes the form of a small projection, since its anterior part is represented merely by fibrous tissue. The **short process** may be looked upon as the upper extremity of the handle projected outwards; it is fixed to the upper part of the membrana tympani by the cartilaginous layer already referred to, and to the extremities of the notch of Rivinus by the anterior and posterior malleolar folds.

The **incus** (Fig. 519 A, C) may be best likened to a bicuspid tooth, with widely

divergent fangs. It consists of a body (corpus incudis), a long process (crus longum), and a short process (crus breve); the two processes form with each other an angle of 90° to 100°. The body and short process are situated in the epitympanic recess. The **body** presents a more or less saddle-shaped surface for articulation with the head of the malleus. This surface is directed forwards, and its lower part is hollowed out for the accommodation of the cog-tooth of the malleus. In front of this hollow it is prominent and spur-like. The **short process** is thick, triangular in shape, and projects horizontally backwards; its conical extremity, covered with cartilage, articulates with the fossa incudis in the postero-inferior part of the epitympanic recess. The **long process** projects, almost perpendicularly, downwards from the body into the tympanic cavity, where it lies parallel with, but $1\frac{1}{4}$ mm. behind and internal to, the handle of the malleus. Its lower end is bent inwards and narrowed to form a short neck, on the inner extremity of which is a small knob of bone, the **processus lenticularis**, for articulation with the head of the stapes. Until the sixth month of fœtal life, this process exists as a separate ossicle, termed the **os orbiculare.**

The **stapes** (Fig. 519, E) presents a head (capitulum stapedis), a neck (collum stapedis), two crura (crus anterius et posterius), and a base or footplate (basis stapedis). The **head**, directed outwards, is concave externally, for articulation with the processus lenticularis of the incus. The **neck** is the slightly constricted part immediately internal to the head, and from it the two crura spring; the tendon of the stapedius muscle is inserted into the posterior aspect of the neck. The anterior crus is shorter and less curved than the posterior. Diverging from each other, the crura are directed inwards and are attached—one near the anterior, the other near the posterior end of the footplate. The **footplate** almost completely fills the oval fenestra, and, like it, is somewhat oval or reniform, its anterior end being the more pointed. In the recent condition a membrane fills the arch formed by the crura and the footplate, the crura being grooved for its reception. In the child the crura of the stapes are less curved than in the adult, and the opening bounded by them and the footplate is nearly triangular.

Articulations of the Tympanic Ossicles.—The joint between the head of the malleus and the body of the incus (articulatio incudomalleolaris) is diarthrodial, and may be described as one of reciprocal reception. It is surrounded by a capsular ligament, from the inner surface of which a wedge-shaped meniscus projects into the joint cavity and incompletely divides it. The articulation of the processus lenticularis and the capitulum stapedis (articulatio incudostapedia) is of the nature of an enarthrosis and is surrounded by a capsular ligament. An interarticular cartilage has been described as occurring in this joint, while some observers deny the presence of a synovial cavity and regard the articulation as a syndesmosis, the articular surfaces being held together merely by fibrous tissue.

Ligaments binding the Ossicles to the Walls of the Tympanic Cavity (lig. ossiculorum auditus).—The malleus is attached to the walls of the tympanum by three ligaments (Fig. 520), viz. anterior, superior, and external. The **anterior ligament** (lig. mallei anterius) consists of two portions: (*a*) the *band of Meckel*, which is attached to the base of the processus longus and passes forwards through the Glaserian fissure to reach the spine of the sphenoid; it was formerly described as the laxator tympani muscle: (*b*) a firm bundle of fibres, the *lig. mallei anterius of Helmholtz*, which extends from the anterior boundary of the notch of Rivinus to the anterior aspect of the malleus, above the base of the processus longus. The **superior ligament** (lig. mallei superius) extends, almost vertically, from the head of the malleus to the roof of the epitympanic recess. The **external ligament** (lig. mallei laterale) is short and fan-shaped; its fibres converge from the posterior half of the notch of Rivinus to the crista mallei. The posterior part of this ligament is strong and constitutes the *ligamentum mallei posticum of Helmholtz.* It forms, together with the ligamentum mallei anterius, the axis around which the malleus rotates, and the two constitute what Helmholtz has termed the "**axis-ligament**" of the malleus.

The posterior extremity of the crus breve of the incus is tipped with cartilage and fixed by means of a ligament, the **ligamentum incudis posterius** (Fig. 520), to the

fossa incudis. Some observers describe this as a diarthrodial joint. A superior ligament, the **ligamentum incudis superius**, is sometimes present, but consists mainly of a fold of mucous membrane. The vestibular surface, and also the circumference of the foot of the stapes, are covered by hyaline cartilage, and a similar layer lines the opening of the fenestra ovalis; that encircling the base of the stapes is joined to that which lines the fenestra by a dense ring of elastic fibres, named the **ligamentum annulare baseos stapedis.** The posterior fibres of this annular ligament are thicker and shorter than the anterior, and thus the anterior end of the foot-plate is free to make greater excursions, during the movements of the bone, than the posterior.

Development of the Tympanic Ossicles.—The malleus and incus are developed from the upper end of Meckel's cartilage (see p. 711). The stapes arises from the mesoblast in the region of the fenestra ovalis and is developed around a small artery, the stapedial artery, which becomes atrophied in man, but persists in many mammals.

Muscles of the Tympanic Cavity.—These are two in number, viz. m. tensor tympani and m. stapedius.

The **m. tensor tympani** is the larger, and takes origin from the roof of the cartilaginous part of the Eustachian tube and from the adjacent part of the great wing of the sphenoid. It also receives some fibres from the bony canal in which it lies, and ends in a tendon which bends outwards, nearly at a right angle to the belly of the muscle, round the pulley-like, posterior extremity of the processus cochleariformis. Passing across the cavity of the tympanum, this tendon is inserted into the inner edge and anterior surface of the manubrium mallei, near its upper end. When the muscle contracts it draws inwards the handle of the malleus, and so renders tense the membrana tympani; it probably also slightly rotates the malleus around its long axis. It receives its nerve from the motor division of the fifth cranial nerve through the otic ganglion.

The **m. stapedius** arises within the pyramid, and from the canal which prolongs the hollow of the pyramid downwards. Its tendon emerges from the apex of the pyramid and is inserted into the posterior surface of the neck of the stapes. On contraction it draws back the head of the stapes, and so tilts the anterior end of the footplate outwards towards the tympanic cavity and the posterior end inwards towards the labyrinth, thus rendering tense the ligamentum annulare—the outward movement of the anterior end of the footplate being greater than the inward movement of its posterior end. The muscle is supplied by the facial nerve.

Movements of the Tympanic Ossicles.—The manubrium mallei follows all the movements of the membrana tympani, while the malleus and incus move together around an axis extending forwards through the short process of the incus and the anterior ligament of the malleus. When the membrana tympani moves inwards it carries with it the handle of the malleus, and the incus, moving inwards at the same time, forces the foot of the stapes towards the labyrinth. This inward movement is communicated to the fluid (perilymph) in the labyrinth and causes an outward bulging of the secondary tympanic membrane, closing the fenestra rotunda. These movements are reversed when the membrana tympani is relaxed, unless the outward movement of the membrane be excessive. In such a condition the incus does not follow the full outward movement of the malleus, but merely glides on this bone at the incudo-malleolar joint, and thus the forcible dragging of the foot of the stapes out of the fenestra ovalis is prevented. The cog-tooth arrangement, already described, on the head of the malleus and body of the incus, causes the incudo-malleolar joint to become locked during the inward movements of the handle of the malleus, the joint becoming unlocked during its outward movements.

Mucous Lining of the Tympanic Cavity (tunica mucosa tympanica).—This is continuous, through the Eustachian tube, with that of the naso-pharynx; it also extends backwards and lines the mastoid antrum and air-cells. Thin, transparent and closely united with the subjacent periosteum, it covers the inner aspect of the membrana tympani and is reflected over the ossicles and their ligaments. It also supplies sheaths for the tendons of the tensor tympani and stapedius muscles, and forms the following **mucous folds**, viz.: (*a*) one from the roof of the epitympanic recess to the head of the malleus and body of the incus; (*b*) one enveloping the chorda tympani nerve and long process of the incus; (*c*) two extending from the

short process of the malleus—one to the anterior, the other to the posterior margin of the notch of Rivinus. A recess, the **pouch of Prussak**, is situated between the membrana flaccida and the neck of the malleus. Communicating behind with the tympanic cavity, this pouch may serve as a reservoir to confine pus or other fluid, since its opening into the tympanum is above the level of its floor, a condition analogous to the opening from the antrum of Highmore into the nasal cavity. The fold of mucous membrane which extends downwards to envelop the chorda tympani nerve gives rise to two pouches, one in front of, and the other behind, the handle of the malleus; these are named the **anterior** and **posterior recesses of Tröltsch.** The epithelium which lines the mucous membrane is flattened over the membrana tympani, promontory and ossicles, but ciliated and columnar over the greater portion of the rest of the cavity.

Vessels and Nerves of the Tympanic Cavity.—The **arteries** which supply the tympanic cavity are: (1) The tympanic artery, a branch of internal maxillary, which reaches the cavity by way of the Glaserian fissure. (2) The stylo-mastoid branch of posterior auricular, which passes through the stylo-mastoid foramen and aqueduct of Fallopius; it supplies branches to the mastoid antrum and air-cells, to the stapedius muscle, to the floor and inner wall of the tympanic cavity, and forms an anastomotic circle, around the membrana tympani, with the tympanic artery. (3) The middle meningeal artery sends a branch to the tensor tympani muscle, and, after entering the skull, gives off its petrosal artery, which is conducted to the tympanum along the hiatus Fallopii; some twigs from the posterior division of the middle meningeal reach the antrum and epitympanic recess through the petro-squamous fissure. (4) The internal carotid artery, in its passage through the canal in the temporal bone, gives off one or two tympanic twigs, while (5) a branch from the ascending pharyngeal accompanies the nerve of Jacobson. The **veins** drain their contents into the pterygoid plexus, the middle meningeal vein, and superior petrosal sinus. The **nerves** which supply the muscles of the tympanic cavity have already been referred to (p. 713). The mucous membrane receives its nerves from the tympanic plexus, which is described on p. 648. The chorda tympani branch of the facial nerve passes from behind forwards through the tympanic cavity.

Early condition of Tympanic Cavity.—During the greater part of intrauterine existence the tympanic cavity is almost completely filled by a soft, reddish, jelly-like embryonic tissue. The narrow, slit-like space is lined by epithelium, which is ciliated over the promontory, but squamous elsewhere. Towards the end of fœtal life, the gelatinous tissue becomes thinned and the cavity correspondingly enlarged. At birth it is filled with fluid which becomes absorbed, coincident with the passage of air from the naso-pharynx, through the Eustachian tube.

INTERNAL EAR.

The innermost, and, at the same time, the essential part of the organ of hearing is situated in the substance of the petrous-temporal bone, and consists of two sets of structures, viz.: (1) a series of cavities hollowed out of the bone and constituting the **bony labyrinth** (labyrinthus osseus); these cavities are continuous with each

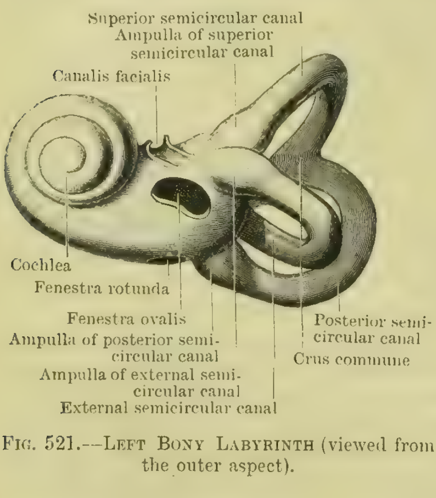


FIG. 521.—LEFT BONY LABYRINTH (viewed from the outer aspect).

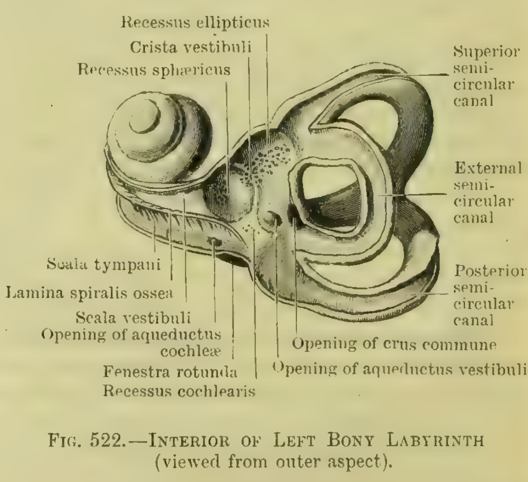


FIG. 522.—INTERIOR OF LEFT BONY LABYRINTH (viewed from outer aspect).

other, and are named from before backwards the **cochlea, vestibule,** and **semicircular canals** (Figs. 521, 522); (2) a complex arrangement of membranous channels (Fig. 524), situated within, but not nearly filling, the bony labyrinth and forming the

membranous labyrinth (labyrinthus membranaceus). These channels are named the **ductus cochlearis, utricle, saccule,** and **membranous semicircular canals**; the utricle and saccule are lodged within the bony vestibule.

OSSEOUS LABYRINTH.

Vestibule.—The vestibule forms the central portion of the osseous labyrinth, and communicates behind with the semicircular canals and in front with the cochlea. It is somewhat ovoid in shape, its long axis being directed forwards and outwards. It measures about 6 mm. antero-posteriorly, 4-5 mm. from roof to floor, and about 3 mm. from without inwards. Its outer wall is directed towards the tympanic cavity, and in it is seen the fenestra ovalis, which, in the recent state, is closed by the foot of the stapes. Its inner wall corresponds with the bottom of the internal auditory meatus and presents, at its antero-inferior part, a rounded depression, the **recessus sphæricus**, which lodges the saccule. This recess is perforated by some twelve or fifteen small foramina, which constitute the **macula cribrosa media** and transmit the filaments of the auditory nerve for the supply of the saccule. The recessus sphæricus is limited above and behind by an oblique ridge, the **crista vestibuli**, the anterior extremity of which is triangular in shape and named the **pyramid** (pyramis vestibuli). Posteriorly, this crista divides into two limbs, between which is a small depression, the **recessus cochlearis** of Reichert, perforated by some eight small foramina, which give passage to the nervous filaments for the supply of the posterior extremity of the ductus cochlearis. Above and behind the crista vestibuli, in the roof and inner wall of the vestibule, is an oval depression, the **recessus ellipticus**, which lodges the utricle. The pyramid and adjacent part of the recessus ellipticus are perforated by some 25 - 30 small apertures, which constitute the **macula cribrosa superior seu major**. The foramina in the pyramid transmit the nerves to the utricle; those in the recessus, the nerves to the ampullary ends of the superior and external semicircular canals. Behind and below the recessus ellipticus is a furrow, gradually deepening to form a canal, the **aqueductus vestibuli**, which passes backwards through the petrous bone and opens, as a slit-like fissure, about midway between the internal auditory meatus and the groove for the lateral sinus. This aqueduct measures 8-10 mm. in length and gives passage to the ductus endolymphaticus and a small vein. The posterior part of the vestibule receives the five rounded apertures of the bony semicircular canals; its anterior part leads, by an elliptical opening, into the scala vestibuli of the cochlea. This opening is bounded inferiorly by a thin osseous lamella, the **lamina spiralis ossea**, which springs from the floor of the vestibule immediately to the outer side of the recessus sphæricus, and forms, in the cochlea, the bony part of the septum between the scala tympani below and the scala vestibuli above. From the anterior part of the floor of the vestibule a narrow cleft, the **fissura vestibuli**, extends forwards into the bony canal of the cochlea. It is bounded internally by the lamina spiralis ossea, just referred to, and externally by a second, smaller lamina, the **lamina spiralis secundaria**, which projects inwards from the outer wall of the cochlea. These two lamina are continuous with each other around the posterior extremity of the fissure.

Semicircular Canals (canales semicirculares ossei).—The semicircular canals (Figs. 521, 522), three in number, are situated above and behind the vestibule. They are distinguished from each other by their position, and are named superior, posterior, and external. They open into the vestibule by five apertures, since the inner extremity of the superior and the upper extremity of the posterior join to form a common canal or crus commune. Differing slightly in length, each forms about two-thirds of a circle, one extremity of which is dilated and termed the ampulla (ampulla ossea). Somewhat compressed laterally, their greatest internal diameter is from 1 to 1·5 mm., whilst the diameter of the ampulla is about 2 mm.

The **superior semicircular canal** (canalis semicircularis superior), 15-20 mm. in length, is vertical and placed transversely to the long axis of the petrous bone. Its convexity is directed upwards, and its position is indicated on the anterior surface of the petrous-temporal by an eminence. Its ampullated end (ampulla ossea

superior) is anterior and external, and opens into the vestibule immediately above that of the external canal. Its opposite extremity joins the non-ampullated end of the posterior canal to form the **crus commune,** which is about 4 mm. in length and opens into the upper and inner part of the vestibule. The **posterior semicircular canal** (canalis semicircularis posterior) is the longest of the three and measures from 18-22 mm. Its ampullary end (ampulla ossea posterior) is placed inferiorly and opens into the lower and back part of the vestibule, where may be seen some six or eight small apertures, forming the **macula cribrosa inferior,** for the transmission of the nerves to this ampulla. Its upper extremity ends in the crus commune. The **external canal** (canalis semicircularis lateralis) is the shortest. It measures from 12-15 mm. and arches nearly horizontally outwards. Of its two extremities the external is ampullated (ampulla ossea lateralis), and opens into the vestibule immediately above the fenestra ovalis and in close relationship to the ampullary end of the superior canal.

Although the three canals are generally regarded as opening into the vestibule by five orifices, some observers incline to the view that the ampullary ends of the superior and external canals form a common orifice, and that, consequently, there are only four openings for the three canals.

Cochlea.[1]—When freed from its surroundings the cochlea assumes the form of a short cone (Fig. 523); the central part of its **base** (basis cochleæ) corresponds

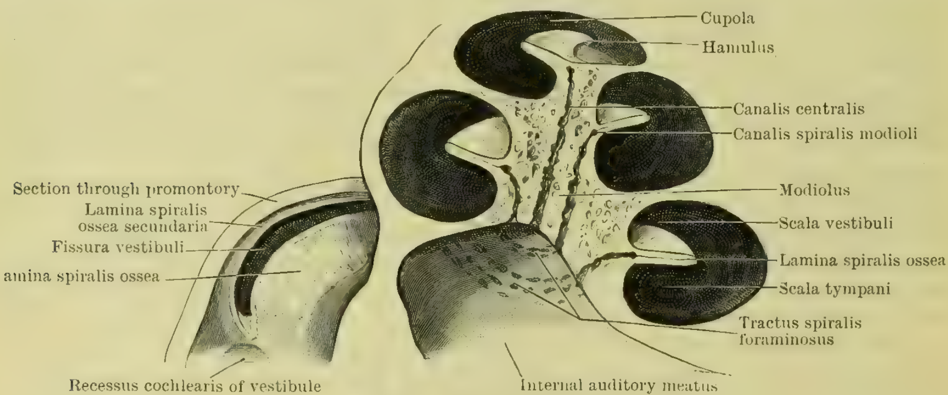


FIG. 523.—SECTION OF BONY COCHLEA.

with the bottom of the internal auditory meatus, whilst its apex or **cupola** is directed forwards and outwards, and comes into close relation with the canal for the tensor tympani muscle. It measures about 9 mm. across the base and about 5 mm. from base to apex, and consists of a spirally-arranged tube, which forms from $2\frac{1}{2}$ to $2\frac{3}{4}$ coils around a central pillar termed the **modiolus.** The length of the tube is from 28 to 30 mm., and its diameter, near the base of the cochlea, 2 mm. Its coils are distinguished by the terms basal, central, and apical; the first, or basal coil, gives rise to the promontory on the inner wall of the tympanum.

The modiolus is about 3 mm. in height and diminishes rapidly in diameter from base to apex, while its tapered extremity fails to reach the cupola by a distance of 1 mm. Its **base** (basis modioli) corresponds with the **area cochleæ** on the fundus of the internal auditory meatus and exhibits the **tractus spiralis foraminosus,** which transmits the nerves for the basal and central coils of the cochlea and the **foramen centrale,** which gives passage to the nerves for the apical coil. The foramina of the tractus spiralis foraminosus traverse the modiolus, at first parallel to its long axis, but, after a varying distance, they bend outwards to reach the attached edge of the lamina spiralis ossea, where they become expanded and form by their apposition a spiral canal, the **canalis spiralis modioli of Rosenthal,** which lodges the **ganglion of Corti,** or **ganglion spirale cochleæ.** From this spiral canal numerous small foramina, for the transmission of vessels and nerves, pass outwards to the free edge of the lamina spiralis. The **lamina spiralis ossea,** a thin, flat shelf of bone, winds round the

[1] In the following description the cochlea is supposed to be placed on its base.

modiolus like the thread of a screw, and, projecting about halfway into the cochlear tube, incompletely divides it into two passages, of which the upper is named the **scala vestibuli**; the lower, the **scala tympani.** The lamina spiralis ossea commences at the floor of the vestibule, near the fenestra rotunda, and ends close to the apex of the cochlea in a sickle-shaped process, the **hamulus**, which assists to form an aperture named the **helicotrema.** In the basil coil the upper surface of the spiral lamina forms almost a right angle with the modiolus, but the angle becomes more and more acute on ascending the tube. In the lower half of the basil coil a second smaller bony plate, the **lamina spiralis secundaria**, projects inwards from the outer wall of the cochlea towards the lamina spiralis ossea, without, however, reaching it. If viewed from the vestibule the slit-like fissura vestibuli, already referred to (p. 715), is seen between the two osseous spiral laminæ. A membrane, the **membrana basilaris**, stretches from the free edge of the lamina spiralis ossea to the outer wall of the cochlea and completes the septum between the scala vestibuli and scala tympani, but the two scalæ communicate with each other through the opening of the helicotrema at the apex of the cochlea. The scala tympani begins at the fenestra rotunda, through which, in the macerated bone, it communicates with the tympanic cavity; in the recent condition the fenestra is closed by the secondary tympanic membrane (*vide* p. 708). At the commencement of the scala tympani a crest, termed the **crista semilunaris**, stretches from the attached margin of the lamina spiralis ossea towards the orifice of the fenestra rotunda. Close to this crest is seen the inner orifice of the **aqueductus cochleæ**, a canal measuring from 10 to 12 mm. in length and opening on the under aspect of the petrous bone internal to the fossa jugularis. Through it there is established a communication between the scala tympani and the subarachnoid space, and through it, also, a small vein passes to join the inferior petrosal sinus. The scala vestibuli, the higher of the two passages, begins in the vestibule; its diameter in the basal coil is less than that of the scala tympani, but in the upper coils it exceeds that of the latter.

From what has been stated, it will be evident that an injection thrown into the scala vestibuli will travel through the helicotrema, and then down the scala tympani as far as the secondary tympanic membrane, and will also pass along the aqueductus cochleæ into the subarachnoid space.

Internal Auditory Meatus.—It is convenient, at this stage, to study the fundus of the internal auditory meatus, which has been referred to as forming the inner wall of the vestibule and the base of the modiolus. It is divided by a transverse ridge, the **crista transversa**, into two parts—an upper or **fossula superior** and a lower or **fossula inferior.** The anterior part of the fossula superior is termed the **area facialis** and exhibits a single large opening, the commencement of the aqueduct of Fallopius, for the transmission of the facial nerve. Its posterior part is named the **area vestibularis superior** and is perforated by the nerves for utricle and ampullæ of the superior and external semicircular canals. The anterior part of the fossula inferior is termed the **area cochleæ** and consists of the **canalis centralis** and the surrounding **tractus spiralis foraminosus**, for the passage of the nerves to the cochlea. Behind the area cochleæ, and separated from it by a ridge, is the **area vestibularis inferior**, which transmits the nerves to the saccule, whilst at the posterior part of the fossula inferior is seen a single foramen, the **foramen singulare**, which gives passage to the nerves for the ampulla of the posterior semicircular canal.

MEMBRANOUS LABYRINTH.

The **membranous labyrinth** (labyrinthus membranaceus) assumes, more or less closely (Fig. 524), the form of the bony labyrinth in which it is situated, but does not nearly fill it. It contains a fluid termed **endolymph**, while the space between it and the bony labyrinth is occupied by a fluid termed **perilymph.** The membranous semicircular canals and the membranous canal of the cochlea follow the course of their bony tubes and lie along the inner aspect of their outer walls. The bony vestibule, on the other hand, contains two chief membranous structures, the **utricle** and **saccule.** The former receives the extremities of the membranous semicircular canals, whilst the latter communicates with the membranous canal of the

cochlea. Moreover, the cavities of the utricle and saccule are indirectly connected, and thus all parts of the membranous labyrinth communicate with each other, and the contained endolymph is free to move from one portion to another. The vestibule, also, contains the ductus endolymphaticus and the commencement of the ductus cochlearis.

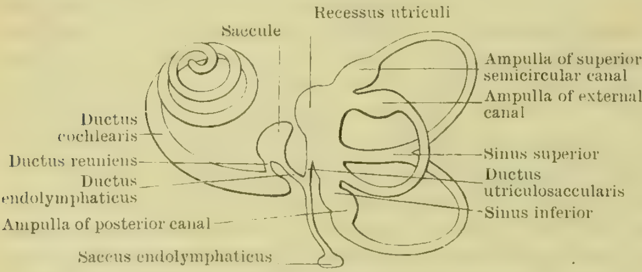


Fig. 524.—Diagrammatic Representation of the Different Parts of the Membranous Labyrinth.

The **utricle** (utriculus), the larger of the two sacs (Fig. 524), occupies the postero-superior portion of the bony vestibule. Its highest part, or **recessus utriculi**, lies in the recessus ellipticus and receives the ampullæ of the superior and external membranous semicircular canals. Its central part receives on its lateral aspect the non-ampullated end of the external canal, and is prolonged upwards and backwards as the **sinus superior**, into which the crus commune of the superior and posterior canals open. The ampulla of the posterior canal opens into its lower and inner part, or **sinus inferior**. The floor and anterior wall of the recessus utriculi are thickened to form the **macula acustica utriculi**, to which are distributed the utricular fibres of the auditory nerve. Whitish in colour, and of an oval or nearly rhombic shape, this macula measures 3 mm. in length and 2·3 mm. in its greatest breadth.

The **saccule** (sacculus) occupies the recessus sphæricus, in the lower and forepart of the vestibule (Fig. 522). Smaller than the utricle, it is of an oval shape and measures 3 mm. in its longest, and about 2 mm. in its shortest diameter. It presents anteriorly an oval, whitish thickening, the **macula acustica sacculi**. This has a breadth of about 1·5 mm., and to it are distributed the saccular fibres of the auditory nerve. The superior extremity of the saccule is directed upwards and backwards, and forms the **sinus utricularis sacculi**, which abuts against, but does not fuse with, the wall of the utricle. From the lower part of the saccule a short canal, the **ductus reuniens** of Hensen, opens into the ductus cochlearis, a short distance in front of its vestibular or blind extremity. A second small channel, the **ductus endolymphaticus**, is continued from the posterior part of the saccule, and, passing between the utricle and the inner wall of the vestibule, is joined by a small canal, the **ductus utriculosaccularis**, which arises from the inner aspect of the utricle. It then enters and traverses the aqueductus vestibuli and ends, under the dura mater on the posterior surface of the petrous bone, in a blind extremity, termed the **saccus endolymphaticus**; this, according to Rüdinger, is perforated by minute foramina, through which the endolymph may pass into the meningeal lymphatics.

The vestibule also contains the blind extremity (cæcum vestibulare) of the ductus cochlearis, which lies immediately below the saccule in the recessus cochlearis of Reichert; from here it passes forwards into the spiral tube of the cochlea.

The walls of the utricle and saccule are composed of connective tissue which blends, along their attached surfaces, with the periosteal lining of the vestibule. It is modified internally to form a homogeneous membrana propria, which is covered by a layer of pavement epithelium and is thickened at the maculæ acusticæ. Towards the periphery of the maculæ the epithelium is cubical, while on them it is columnar.

The **structure of the maculæ** in the utricle and saccule is practically the same; two kinds of cells are found, viz. (*a*) supporting cells, and (*b*) hair cells. The **supporting cells** are somewhat fusiform, each containing, near its middle, a nucleus. Their branched, deep extremities are attached to the membrana propria; their free ends lie between the hair cells and form a thin inner limiting cuticle. The **hair cells** are flask-shaped and do not reach the membrana propria, but end in rounded extremities which lie between the supporting cells. Each contains, at its deepest part, a large nucleus, the rest of the cell being granular and pigmented. From the free end of each there projects a stiff hair-like process, which, on the application of

reagents, splits into several finer filaments. The nerve fibres pierce the membrana propria and end in arborisations around the deep extremities of the hair cells. A collection of small, rhombic crystals of carbonate of lime, termed **otoconia**, adheres to each of the maculæ.

The **membranous semicircular canals** (ductus semicirculares) are elliptical on transverse section (Fig. 525) and possess a calibre equal to about one-fourth of that of the bony tubes, to the greater circumference of which they are attached. The peripheral portion of the ellipse is fixed to the periosteal lining of the bony canal, whilst the opposite part is free, except that it is connected by irregular bands, the **ligamenta labyrinthi canaliculorum**, which pass through the perilymphatic space to the bony wall. The membranous canals are dilated in the bony ampullæ and the membranous ampullæ (ampullæ membranaceæ) are distinctly marked off from the concave aspect of the canals.

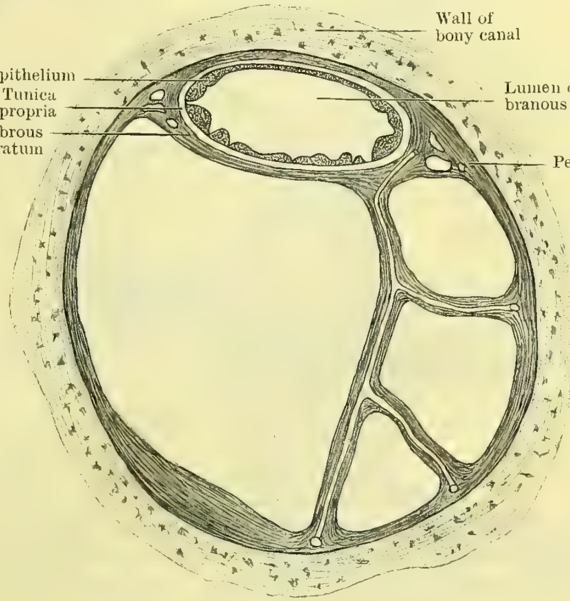


FIG. 525.—TRANSVERSE SECTION OF HUMAN SEMICIRCULAR CANAL (Rüdinger).

Each membranous canal consists of three layers, viz.: (*a*) an outer **fibrous stratum** which contains blood-vessels, together with some pigment, and fixes the tube to the bony wall; (*b*) an intermediate, transparent **tunica propria**, presenting a number of papilliform elevations which project towards the lumen. The fibrous layer and tunica propria are thinnest along the attached surface of the tube, and in this region also the papilliform elevations are absent; (*c*) an internal **epithelial layer**, composed of pavement cells. In the ampullæ the tunica propria is much thickened and projects into the cavity as a transverse elevation, termed the **septum transversum**, which, when seen from above, is somewhat fiddle-shaped; its most prominent part is covered by auditory epithelium forming the **crista acustica**, at each end of which is a half-moon-shaped border of small columnar cells, the **planum semilunatum**. The cells covering the crista acustica consist of **supporting cells** and **hair cells**, and are similar in their arrangement to those in the maculæ of the utricle and saccule. The hairs of the hair cells are, however, considerably longer, and project as far as the middle of the ampullary lumen. In fresh specimens they appear to end free, but in hardened preparations are seen to terminate in a soft, clear, dome-like structure, the **cupola terminalis**, which is striated, the striæ converging towards its concavity. The nerves form arborisations around the bases of the hair cells.

The **membranous cochlea** (ductus cochlearis or scala media) commences in the recessus cochlearis of the vestibule by a blind extremity (cæcum vestibulare), close to which it receives the ductus reuniens of Hensen (*vide* p. 718). It forms a spirally-arranged canal inside the bony cochlea and ends at the apex of the latter in a second blind extremity, the **lagena**, or cæcum cupulare, which is fixed to the cupola and partly bounds the helicotrema. As already stated (*vide* p. 717), the membrana basilaris extends from the free edge of the lamina spiralis ossea to the outer wall of the cochlea. A second, more delicate membrane, the **membrane of Reissner**, or membrana vestibularis, stretches from the thickened periosteum covering the upper surface of the lamina spiralis ossea to the outer cochlear wall, some little distance

above the external attachment of the membrana basilaris. A canal is thus enclosed between the underlying scala tympani and the overlying scala vestibuli, and constitutes the membranous cochlea or **ductus cochlearis.** Triangular on transverse

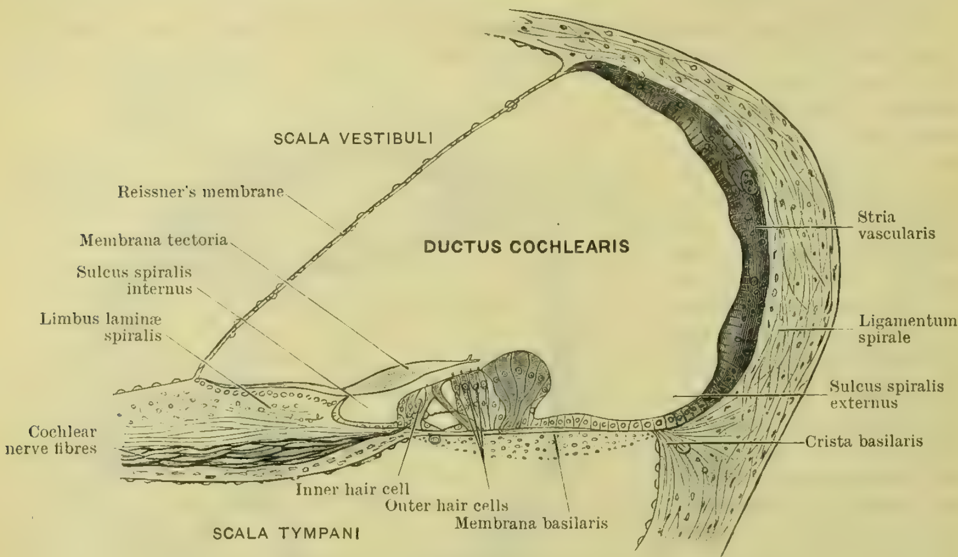


FIG. 526.—SECTION ACROSS THE DUCTUS COCHLEARIS (Retzius).

section, it possesses a roof, outer wall, and floor, and is lined throughout with epithelium and filled with endolymph. On its floor the epithelium is greatly modified, and here are found the endings of the cochlear division of the auditory nerve.

The **roof** or **vestibular wall** of the ductus cochlearis is formed by the membrane of Reissner, which consists of a delicate, nearly homogeneous membrane, covered on its two surfaces by a layer of epithelium. Its entire thickness is about 3 μ.

The **outer wall** of the ductus cochlearis (Fig. 527) consists of the periosteal lining of the bony cochlea, which, however, is much thickened and greatly modified to form what is termed the **ligamentum spirale cochleæ.** Occupying the whole outer wall, this ligament projects inwards inferiorly as a triangular prominence, the **crista basilaris,** to which the outer edge of the membrana basilaris is attached. The fibres of the membrane radiate into the ligament in the form of a series of bundles analogous to the ligamentum pectinatum iridis. In the upper part of the ligamentum spirale the periosteum is of a reddish-yellow colour and contains, immediately under its epithelial lining, numerous small blood-vessels and capillary loops, forming the **stria vascularis.** The lower limit of this stria is bounded by a prominence, the **prominentia spiralis,** in which is seen a vessel, the **vas prominens,** and between this prominence and the crista basilaris is a concavity, the **sulcus spiralis externus.** The height of the outer wall diminishes towards the apex of the cochlea.

The **floor** or **tympanal wall** of the ductus cochlearis is formed by the periosteum covering that portion of the lamina spiralis ossea which is situated to the outer side of Reissner's membrane, and by the **membrana basilaris,** which stretches from the free edge of the lamina spiralis ossea to the crista basilaris. On the inner part of the membrana basilaris, the complicated structure termed the **organ of Corti** is placed. The lamina spiralis ossea consists of two plates of bone, between which are placed the canals for the branches of the cochlear nerve. On the upper plate the periosteum is thickened and modified to form the **limbus laminæ spiralis,** the outer extremity of which forms a C-shaped concavity, the **sulcus spiralis internus.** The portions of the limbus which project outwards, above and below this concavity, are termed respectively the **labium vestibulare** and **labium tympanicum.** The latter is perforated by some 4000 small apertures, the **foramina nervosa** or habenula perforata, for the transmission of the cochlear nerves. Externally it becomes continuous with the

membrana basilaris. The upper surface of the labium vestibulare presents a number of furrows crossing each other, nearly at right angles, and intersecting a series of elevations which, at the free margin of the labium, form a row of tooth-like structures, some 7000 in number, the **auditory teeth of Huschke.** Covering the limbus is a layer of apparently squamous epithelium; the deeper protoplasmic portions of the cells, however, with their contained nuclei, fill up the intervals between the elevations and auditory teeth, and are continuous with the cells lining the sulcus spiralis internus.

Membrana Basilaris.—The inner part of this membrane is thin, and supports the organ of Corti; it is named the **zona arcuata**, and reaches as far as the footplate of the outer rod of Corti. Its outer part, extending from the footplate of the outer rod of Corti to the crista basilaris, is thicker and distinctly striated, and is termed the **zona pectinata.** The substantia propria of the membrane is almost homogeneous, but exhibits, in its deeper part, numerous fibres. These fibres are most distinct in the zona pectinata, and number, according to Retzius, about 24,000. Covering the under surface of the membrana basilaris is a layer of connective tissue, which contains, in its inner part, small blood-vessels, one of which, larger than the rest, lies below the tunnel of Corti and is named the vas spirale. The width of the membrana basilaris increases from 210 μ in the basil coil to 360 μ in the apical coil.

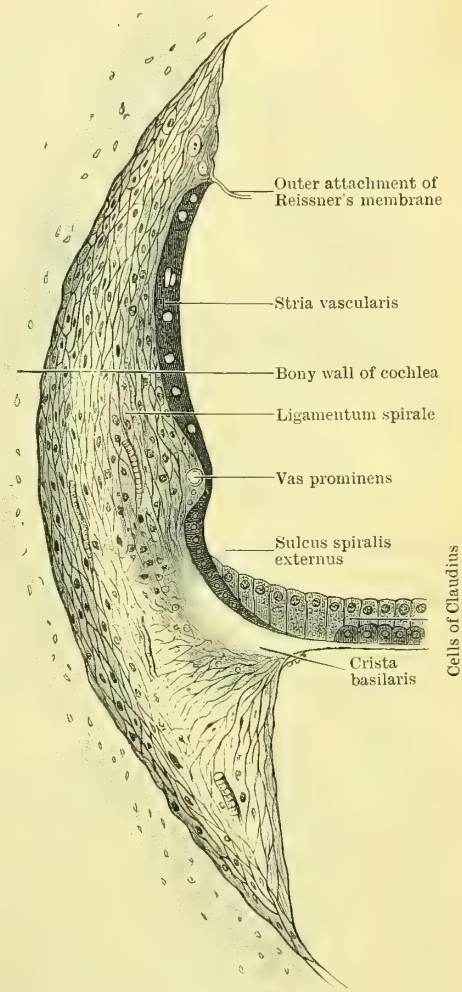


Fig. 527.—Transverse Section through Outer Wall of Ductus Cochlearis (Schwalbe).

Organ of Corti (Fig. 528).—Placed upon the inner portion of the membrana basilaris, the organ of Corti consists of an epithelial eminence which extends along the entire length of the ductus cochlearis and comprises the following structures, viz.: (1) Corti's rods or pillars, (2) hair cells (inner and outer), (3) supporting cells of Deiters, (4) the cells of Hensen and Claudius, (5) the lamina reticularis, and (6) a cuticular membrane, the membrana tectoria.

The **rods of Corti** form two rows, **inner** and **outer**, of stiff, pillar-like structures, and each rod presents a base or footplate, an intermediate elongated portion, and an upper end or head. The bases of the two rows are planted on the membrana basilaris, some little distance apart. The intermediate portions incline towards each other and the heads come into contact, so that, between the two rows above and the membrana basilaris below, there is enclosed a triangular tunnel, the **tunnel of Corti**; this tunnel increases both in height and width on passing towards the apex of the cochlea. The **inner rods** number nearly 6000, and the head of each resembles somewhat the upper end of the ulna, presenting a deep concavity, externally, for the reception of a corresponding convexity on the head of the outer rod. The part of the head which overhangs this concavity is prolonged outwards, under the name of the **head plate**, and overlaps the head of the outer rod. The expanded bases of the inner rods are situated on the innermost portion of the membrana basilaris, immediately to the outer side of the foramina nervosa of the labium tympanicum. The intermediate parts of the inner rods are sinuously curved, and form, with the membrana basilaris, an angle of about 60°. The **outer rods** number about 4000, and are longer

than the inner, especially in the upper part of the cochlea. They are more inclined towards the membrana basilaris, and form with it an angle of about 40°. The head of each is convex internally, to fit the concavity on the head of the inner rod, and is prolonged

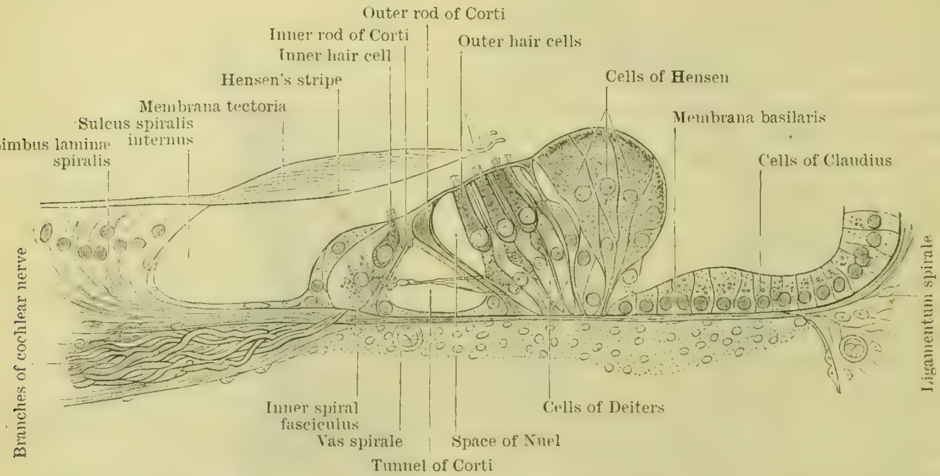


FIG. 528.—TRANSVERSE SECTION OF CORTI'S ORGAN FROM THE CENTRAL COIL OF COCHLEA (Retzius).

outwards as a plate, the **phalangeal process**, which becomes connected with the lamina reticularis. In the head is an oval body which has an affinity for certain reagents. The main part of each rod consists of a nearly homogeneous material, which is finely striated. At the base of each, on its tunnel side, is a nucleated mass of protoplasm which reaches as far as the heads of the rods, and covers also the greater part of the tunnel floor. This may be regarded as the undifferentiated part of the cell from which the rod was developed. Slit-like intervals, for the transmission of nerves, exist between the intermediate portions of adjacent rods.

Hair Cells.—These, like Corti's rods, form two sets, **inner** and **outer**. The former consists of a single row lying immediately internal to the inner rods—the latter of three, or, it may be, four rows placed to the outer side of the external rods. The **inner hair cells** are about 3500 in number, and have a greater diameter than the inner rods, and so each is supported by more than one rod. Somewhat oval in shape, their free extremities are surmounted by about twenty fine hair-like processes, arranged in the form of a crescent, with its concavity directed inwards. The deep end of the cell is rounded, and contains a large nucleus. It reaches only about half-way down the rod, and in contact with it are the arborisations of the nerve terminations. To the inner side of this row of hair cells are two or three rows of elongated columnar cells, which act as supporting cells and are continuous with the low columnar cells lining the sulcus spiralis internus. The **outer hair cells** number about 12,000, and form three rows in the basal coil and four rows in the upper two coils, although in the higher coils the rows are not so regularly arranged. Their rounded free extremities support some twenty hairlets arranged in the form of a crescent, opening inwards. Their deep extremities reach about half-way to the membrana basilaris, and are in contact with the nerve arborisations.

Alternating with the rows of the outer hair cells are the rows of **Deiters' supporting cells**, the lower extremities of which are expanded on the membrana basilaris, whilst their upper ends are tapered; the nucleus is placed near the middle of each cell, and, in addition, each cell contains a bright, thread-like structure, called the **supporting fibre.** This fibre is attached, by a club-shaped base, to the membrana basilaris, and expands, at the free end of the cell, to form a **phalangeal process** of the membrana reticularis.

The **cells of Hensen**, or outer supporting cells, consist of about half a dozen rows, immediately outside Deiters' cells, and form a well-marked elevation on the floor of the ductus cochlearis. Their deep extremities are narrow and attached to the membrana basilaris, while their free ends are expanded; each cell contains a distinct nucleus and some pigment granules. The columnar cells, situated externally to the cells of Hensen, cover the outer part of the zona pectinata, and are named the **cells of Claudius.** A space, the **space of Nuel**, exists between the outer rods of Corti and the neighbouring row of hair cells. It communicates internally with Corti's tunnel, and extends outwards between the outer hair cells as far as Hensen's cells.

The **lamina reticularis** is a thin cuticular structure, which lies over Corti's organ and extends from the heads of the outer rods as far as Hensen's cells, where it ends in a row of quadrilateral areas, which form its outer border. On looking at it from above, it is seen to consist of two or three rows of structures, named **phalanges,** which are elongated cuticular plates, resembling in shape the digital phalanges. The innermost row is formed by the phalangeal processes of the heads of the outer row of Corti's rods; the succeeding row, or rows, represent the expanded upper ends of Deiters' supporting cells. The number of rows of phalanges, therefore, varies with the number of rows of outer hair cells and the alternating cells of Deiters. The phalanges separate the free ends of the hair cells from each other, since these are seen to occupy the somewhat circular apertures between their constricted middle portions.

The **membrana tectoria** (Fig. 528) is an elastic membrane overlying the sulcus spiralis internus and the organ of Corti. Attached, by its inner end, to the limbus laminæ spiralis, near the lower edge of Reissner's membrane, it reaches outwards as far as the outer row of hair cells. Its inner portion is thin and overlies the auditory teeth of Huschke. Its outer part is, at first, much thickened, but becomes attenuated near its external border, which, according to Retzius, is attached to the outer row of Deiters' cells. Its lower edge presents a firm, homogeneous border, and opposite the inner row of hair cells contains a clear, spirally-arranged band, named **Hensen's stripe.** Probably the membrana tectoria acts as a damper comparable to the otoconia in the utricle and saccule.

Auditory Nerve (Fig. 529).—The auditory nerve divides into two main parts, the **ramus vestibularis** and the **ramus cochlearis**; as the former traverses the internal

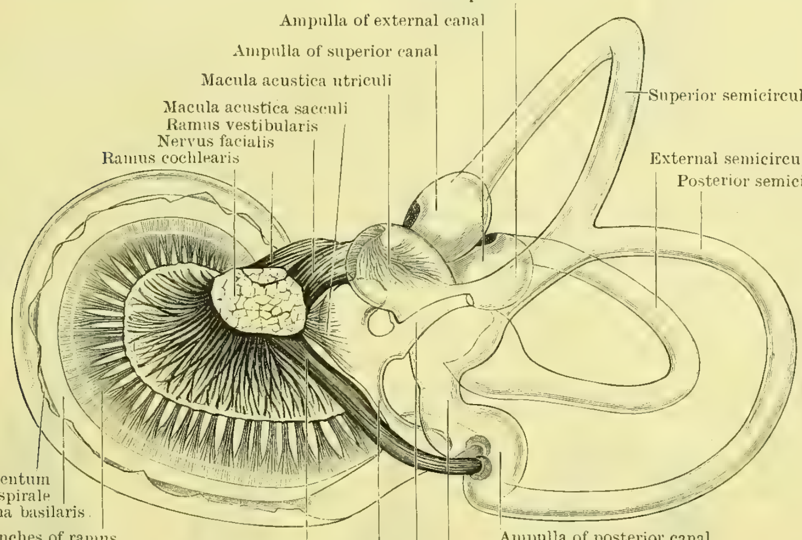


Fig. 529.—Membranous Labyrinth of a Five Months' Fœtus, viewed from its postero-mesial aspect (Retzius).

auditory meatus it presents a gangliform swelling, the **ganglion of Scarpa.** The ramus vestibularis divides into three branches, which are distributed to the macula acustica utriculi and the ampullæ of the superior and external semicircular canals. The ramus cochlearis gives off a branch to the macula acustica sacculi and another to the ampulla of the posterior semicircular canal. The remainder of the ramus cochlearis is distributed to the hair cells of Corti's organ, the branches for the basal and middle coils entering the foramina in the tractus spiralis foraminosus, those for the apical coil passing up through the canalis centralis of the modiolus. Extending upwards, in the bony canals of the modiolus, the nerve fibres radiate outwards between the lamellæ of the lamina spiralis ossea. Contained in the spiral canal of the modiolus, near the attached margin of the lamina, is a ganglion which winds spirally round the modiolus, and is named the **ganglion spirale** or ganglion of

Corti (Fig. 530). It consists of bipolar nerve-cells, and each nerve fibre, probably, has its continuity interrupted by one of these cells. Beyond the ganglion spirale the nerve fibres extend outwards, at first in bundles, and then in a more or less continuous sheet, from the outer edge of which they are again collected into bundles, which pass through the foramina nervosa of the labium tympanicum. Beyond this they appear as naked axis-cylinders, and, turning in a spiral manner (**inner** or **first spiral fasciculus**), send fibrillæ towards the inner row of hair cells. Other fibrils pass outwards between the inner rods and form a **second spiral fasciculus** in Corti's tunnel, from which fibrils extend outwards across the tunnel, and, passing between the outer rods, enter Nuel's space. They form a spiral fasciculus on the inner aspect of each row of Deiters' cells, and from these fasciculi fibrillæ pass towards the bases of the outer hair cells.

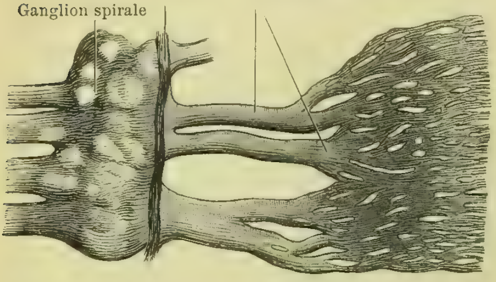


Fig. 530.—Part of Cochlear Nerve, highly magnified (Henle).

Schwalbe divides the auditory nerve into three portions, viz.: (1) **ramus utriculo-ampullaris,** corresponding with the ramus vestibularis already described; (2) **ramus sacculo-ampullaris,** for the saccule and posterior ampulla; and (3) **ramus cochlearis,** for the ductus cochlearis.

Vessels of the Internal Ear.—The **auditory artery,** a branch of the basilar, enters the internal auditory meatus and divides into vestibular and cochlear branches. The vestibular branch supplies the soft tissues in the vestibule and semicircular canals, each canal receiving two arteries, which, starting from opposite extremities of the canal, anastomose on the summit of the arch. The cochlear branch divides into numerous twigs, which enter the foramina in the tractus spiralis foraminosus and run outwards in the lamina spiralis ossea to reach the soft structures; the largest of these arteries runs in the canalis centralis. The stylo-mastoid artery also supplies some minute branches to the cochlea. Siebenmann describes the auditory artery as dividing into three branches, viz.: (1) anterior vestibular, (2) cochlear proper, and (3) vestibulo-cochlear. The **veins** from the cochlea and vestibule unite at the bottom of the meatus with the veins from the semicircular canals to form the **internal auditory vein,** which may either open into the posterior part of the inferior petrosal sinus or into the lateral sinus. Small veins also pass through the aqueductus cochleæ and aqueductus vestibuli, the former opening into the inferior petrosal sinus or into the internal jugular vein, the latter into the superior petrosal sinus.

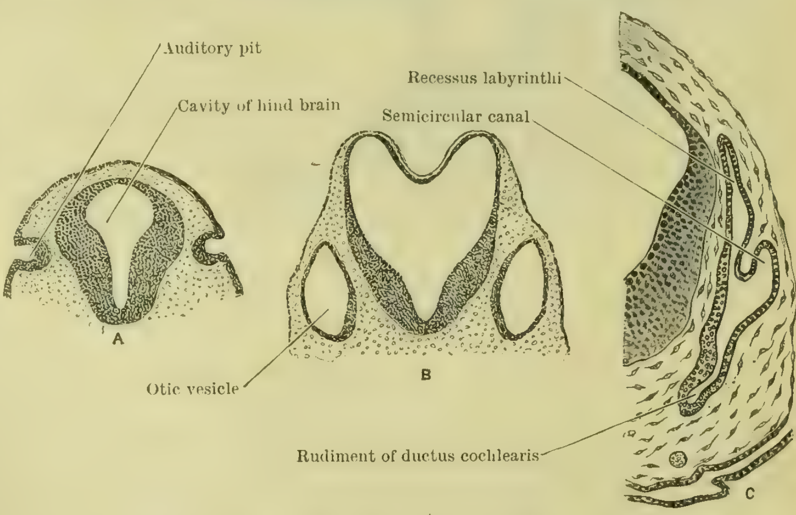


Fig. 531.—Sections through the Region of the Hind Brain of Fœtal Rabbits (to illustrate the development of the labyrinthine epithelium).

In A the epiblast is invaginated to form the auditory pit; in B the auditory pit is closed and detached from the epiblast, forming the otic vesicle; while C shows a further stage in the development of the vesicle.

Development of Labyrinth.

The epithelial lining of the labyrinth is derived from an invagination of the cephalic ectoderm, termed the **auditory pit,** which appears opposite the hind brain immediately above the first visceral cleft. The mouth of the pit is closed by the growing together of its margins, and it then assumes the form of a hollow vesicle, the **otic vesicle,** lined by epithelium; the vesicle sinks into the subjacent mesoderm and is met by the auditory

nerve growing out from the neural crest. The vesicle soon becomes pear-shaped; its upper tapering part is named the **recessus labyrinthi,** and forms the future ductus endolymphaticus. About the fifth week, the lower part of the vesicle is prolonged forwards as a tubular elongation, the future ductus cochlearis. This is at first straight, but soon becomes curved on itself, so that at the twelfth week all three coils are differentiated. From the upper part of the vesicle the semicircular canals are developed and appear as hollow disc-like evaginations, the central parts of the two walls of which coalesce and disappear, leaving only the peripheral rings or canals. The three canals are free about the beginning of the second month, and are developed in the following order, viz.: superior, posterior, and external. The intermediate part of the otic vesicle represents the vestibule, and is divided by a constriction into an anterior part, the saccule, communicating with the ductus cochlearis, and a posterior portion, the utricle, receiving the extremities of the semicircular canals. The constriction extends for some distance into the ductus endolymphaticus, and thus the utricle and saccule are only indirectly connected by a Y-shaped tube. Another constriction makes its appearance between the saccule and the ductus cochlearis, near its commencement, and forms the **canalis reuniens** of Hensen. The epithelial lining is at first columnar, but becomes cubical throughout the whole labyrinth, except opposite the terminations of the auditory nerve, where it forms the columnar epithelium of the maculæ of the utricle and saccule, of the cristæ ampullæ, and of the organ of Corti. On the floor of the ductus cochlearis two ridges appear, of which the inner forms the limbus laminæ spiralis, whilst the cells of the outer become modified to form the rods of Corti, the hair cells, and the supporting cells of Deiters and Hensen.

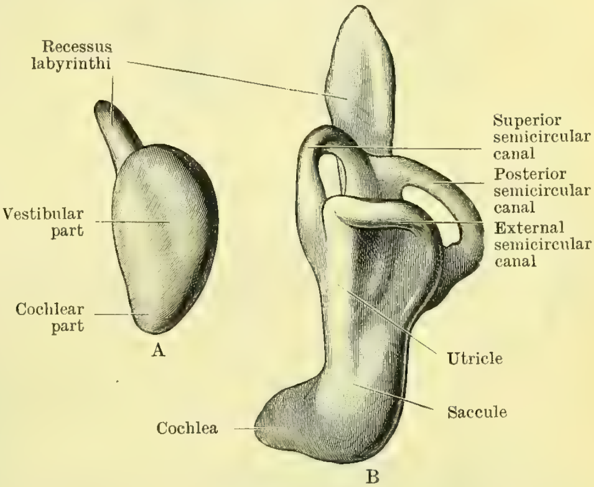


FIG. 532.

A, Left labyrinth of a human embryo of about four weeks; B, Left labyrinth of a human embryo of about five weeks (from W. His, jun.).

The mesoderm surrounding the otic vesicle is differentiated into: (1) a fibrous layer, the wall of the membranous labyrinth; (2) a cartilaginous external capsule, the future petrous bone; and (3) an intervening layer of gelatinous tissue, which is ultimately absorbed to form the perilymphatic space between the bony and membranous labyrinths.

ORGANS OF TASTE.

The peripheral organs of the sense of taste (organon gustus) consist of groups of modified epithelial cells, termed the **taste buds**, which are found on certain parts of the tongue and its immediate neighbourhood.

Taste buds are present in large numbers around the circumference of the papillæ vallatæ, while some are also found on their opposing walls (Fig. 533). They are very numerous over the fimbriæ linguæ, which correspond with the papillæ foliatæ of the tongue of the rabbit, and are also found over the posterior part and sides of the tongue, either on the papillæ fungiformes or throughout the stratified epithelium. They exist, also, on the buccal surface of the soft palate and on the posterior aspect of the epiglottis.

Structure of Taste Buds (Fig. 534).—They are oval or flask-shaped, and occupy nests in the stratified epithelium of the regions mentioned. The deep extremity of each is somewhat expanded and rests upon the corium; the free end is perforated by a minute pore, termed the **gustatory pore**. They consist of modified epithelial cells, which are grouped under the two varieties of—(*a*) supporting cells, and (*b*) gustatory cells (Fig. 535). The **supporting cells** are elongated, nucleated

spindles, and are mostly arranged like cask staves to form the outer envelope of the bud. Some are, however, found in the interior of the bud, amongst the **gustatory**

FIG. 533.

A, Section through a papilla vallata of human tongue. B, Section through a part of the papilla foliata of a rabbit.

1. Papilla. 2. Vallum. 3. Taste buds. 4. Papillæ. 5. Taste buds. 6. Duct of serous gland.

cells. The latter occupy the centre of the bud, and present a nucleated cell-body, which is prolonged into a peripheral and a central process. The peripheral process

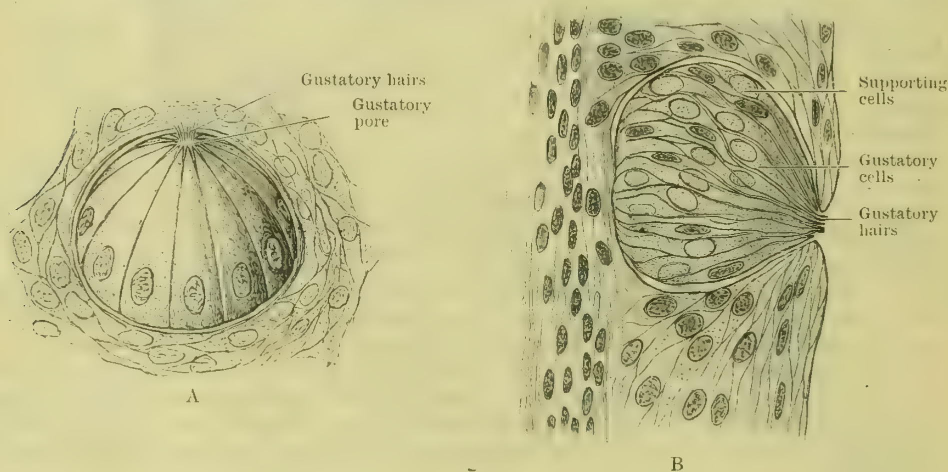


FIG. 534.

A, Three-quarter surface view of taste bud from the papilla foliata of a rabbit (highly magnified). B, Vertical section of taste bud from the papilla foliata of a rabbit (highly magnified).

is rod-like and almost hyaline, and terminates at the gustatory pore in a hair-like filament, the **gustatory hair**. The central process passes inwards towards the deep extremity of the bud, where it ends free, either in a single varicose filament or by becoming bifurcated or branched.

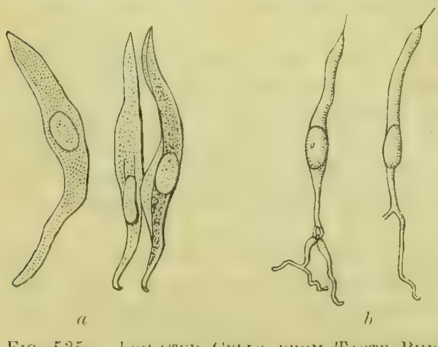


FIG. 535.—ISOLATED CELLS FROM TASTE BUD OF RABBIT (Engelmann).

a, Supporting cells. *b*, Gustatory cells.

Nerves of Taste.—The nerve which supplies the taste buds over the anterior part of the tongue is probably the chorda tympani branch of the facial nerve; that for the posterior part, the glosso-pharyngeal. The internal laryngeal branch of the vagus nerve supplies the epiglottis, together with a small area of the tongue immediately in front of it. The nerve fibrils, having lost their medullary sheath, ramify partly between the gustatory cells and partly amongst the cells of the bud capsule.

It was formerly thought that the nerve fibrils were directly continuous with the central ends of the gustatory cells, but this view is no longer entertained.

The ducts of Ebner's glands open into the bottom of the valleys surrounding the papillæ vallatæ, and the serous-like secretion of these glands probably washes the free hair-like extremities of the gustatory cells, and so renders them ready to be stimulated by successive substances. It should be added that there is a close association between the senses of smell and taste. This can be best appreciated by considering the defective taste perceptions resulting from inflammatory conditions of the nasal mucous membrane or the common practice of holding the nose in order to minimise the taste of nauseous drugs.

THE SKIN OR INTEGUMENT.

ORGANS OF TOUCH.

The Skin.

The **skin** (integumentum commune) covers the body, and is continuous, at the orifices on its surface, with the mucous lining of its alimentary and other canals. It contains the peripheral terminations of the sensory nerves, and serves as an organ of protection to the deeper tissues. It is the chief factor in the regulation of the body temperature, and by means of the sweat and sebaceous glands, which open on its free surface, constitutes an important excretory structure. Its superficial layers are modified to form appendages in the shape of hairs and nails.

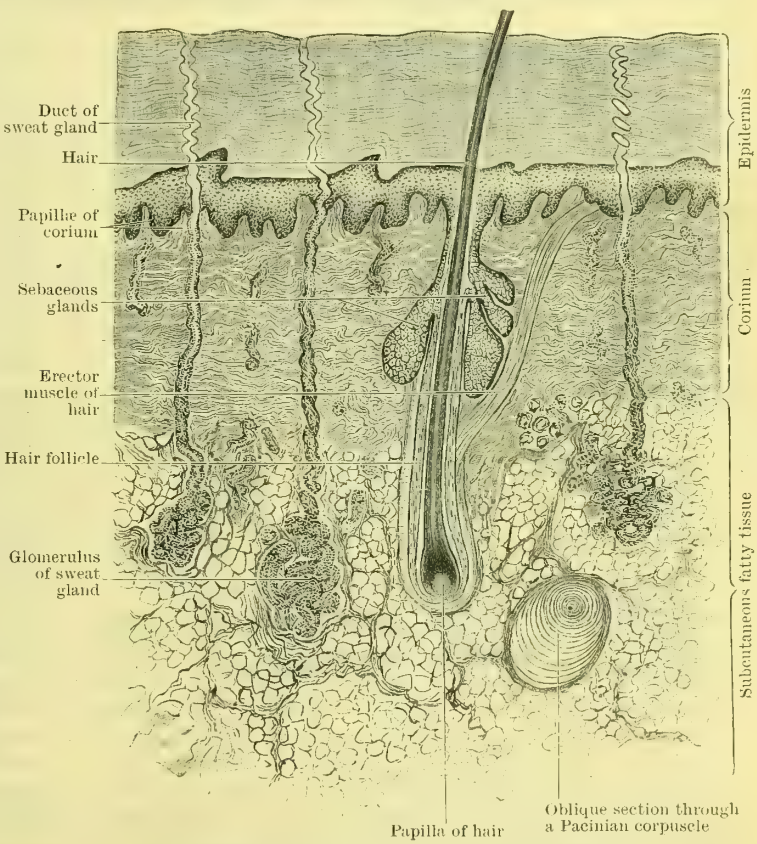


Fig. 536.—Vertical Section of the Skin (schematic).

The superficial area of the skin averages about one and a-half square metres, whilst its thickness varies from 0·5 to 4 mm., being greatest on the palms of the hands and soles of the feet, and on the back of the neck and shoulders, and least on the eyelids and penis. It is very elastic and resistant, and its colour, determined partly by its own pigment and partly by that of the blood, is deeper on exposed parts and in the regions of the genitals, axillæ, and mammary areolæ, than elsewhere. The colour also varies with race and age, the different races of the world being roughly classified, according to the colour of their skin, into the three groups of white, yellow, and black Pinkish in colour in childhood, the

skin assumes a yellowish tinge in old age, while in certain diseases (*e.g.* icterus and melasma Addisonii) it undergoes marked alteration.

The surface of the skin is perforated by the hair follicles and by the ducts of the sweat and sebaceous glands, and on the palms, soles, and flexor aspect of the digits it presents numerous permanent ridges (cristæ cutis), which correspond with rows of underlying papillæ. Over the terminal phalanges these ridges form distinctive patterns, which are retained from youth to old age, and may be utilised for purposes of identification. Folds of the skin (retinacula cutis) are seen in the neighbourhood of the joints, and it can be thrown into wrinkles by the contraction of the subcutaneous muscles, where these exist. Over the greater part of the body it is freely movable; but on the scalp and outer surface of the pinna, as well as on the palms and soles, it is bound down to the subjacent tissues.

The skin consists of two strata, viz.: a deep, termed the dermis or corium, and a superficial, named the epidermis (Fig. 536).

The **corium** gives elasticity and sensibility to the skin, and consists essentially of a felted interlacement of connective tissue and elastic fibres. In its deeper part, or **stratum reticulare**, the fibrous bundles are coarse and form an open network, in the meshes of which are vessels, nerves, pellets of fat, hair follicles, and glands. This reticular stratum passes, as a rule, without any line of demarcation, into the panniculus adiposus or subcutaneous fatty tissue, but in some parts it rests upon a layer of striped or unstriped muscular fibres—the latter in the case of the scrotum. In the superficial layer, or **stratum papillare**, of the corium, the connective tissue-bundles are finer and form a close network. Projecting from its free surface are numerous finger-like, single, or branched elevations, termed **papillæ** (Fig. 537), the free ends of which are received into corresponding depressions on the under surface of the epidermis. These papillæ vary in size, being small on the eyelids, but large on the palms and soles, where they may attain a length of 225 μ and produce the permanent curved ridges already alluded to. Each ridge usually contains two rows of papillæ, between which the ducts of the sweat glands pass to reach the surface. The papillæ consist of fine connective tissue and elastic fibres, mostly arranged parallel to the long axis of the papilla. The majority contain capillary loops, but some the terminations of nerves. The superficial surface of the corium is covered by a thin homogeneous basement membrane.

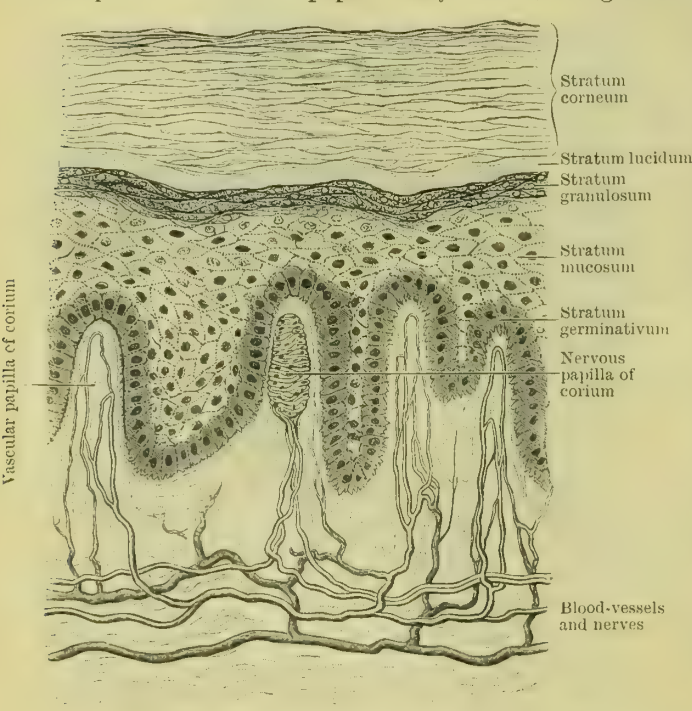


Fig. 537.—Vertical Section of Epidermis and Papillæ of Corium (highly magnified).

The **epidermis** covers the corium; it is non-vascular and consists of stratified epithelium. Its superficial layers are modified to form the **stratum corneum** or **horny layer** of the skin, which may be separated by maceration or blistering from the deeper, softer portion, or **stratum mucosum** (Malpighi). The epidermis consists from within outwards of the following five strata (Fig. 537):—

1. The **basilar layer** or **stratum germinativum**, comprising a single stratum of

nucleated columnar cells planted by denticulated extremities on the basement membrane of the corium.

2. The **stratum mucosum**, consisting of six or eight layers of polygonal, nucleated "prickle" or "finger" cells, the processes of which join those of adjacent cells. Between the cells of this layer are minute channels, in which leucocytes or pigment granules may be seen. The cells of the stratum mucosum are characterised by the presence of numerous epidermic fibrils, which are coloured violet by hæmatoxylin and red by carmine. These fibrils are unaffected by boiling, but swell up under the action of acids and alkalies and form the filaments of union between adjacent cells. On account of their presence, L. Ranvier (*Compt. rend.*, Paris, Jan. 1899, tome cxxviii.) has named this layer the **stratum filamentosum**. The dark colour of the negro's skin is caused by the presence of numerous pigment granules in the deeper layers of this stratum; the pigment—of which *melanin* forms an important constituent—is absent from the more superficial layers of the epidermis.

3. The **stratum granulosum**, consisting of two or three layers of horizontally arranged, flattened cells, scattered around the nuclei of which are elliptical or spherical granules of *eleidin*, a substance staining deeply with carmine, and probably representing an intermediate stage between the protoplasm of the deeper cells and the keratin of the superficial layers.

4. The **stratum lucidum**, an apparently homogeneous layer, but in reality made up of several strata of flattened or irregular squames, some of which may contain eleidin granules.

5. The **stratum corneum**, which comprises several layers of flattened, keratinised squames, from which the nuclei have disappeared. The superficial layers of this stratum are constantly removed by friction and as constantly replaced by the deeper cells, which undergo keratinisation as they approach the surface.

L. Ranvier (*op. cit.*) has pointed out that the **stratum lucidum** is really double, and has named the deeper of its two layers the **stratum intermedium**; this he describes as consisting of two or three layers of clear cells with atrophied nuclei, while in the cell-walls the epidermic fibrils "are rolled up like the threads of a cocoon." He has also applied the term **stratum disjunctum** to the partly-detached cells on the free surface of the stratum corneum. Ranvier (*Arch. Anat. Micr.* 1898, tome ii. fasc. iv.) has likewise shown that the cells of the stratum corneum contain granules of a fatty material having the consistency and plasticity of beeswax.

Regeneration of the epidermis is generally regarded as taking place by cell proliferation in the stratum germinativum, the young cells gradually passing through the polyhedral and granular stages, and ultimately becoming the horny squames of the stratum corneum. Professor Thomson of Oxford considers that, although this view meets all the requirements in white races, a difficulty is met with if it is applied to coloured races, where most pigment is found in the deeper cells of the stratum mucosum, while the superficial layers are free from colour. If the deeper cells advance to the surface, it is only reasonable to suppose that they would carry their pigment with them. This theory, therefore, necessitates a satisfactory explanation of the disappearance of the pigment from the superficial layers. He suggests that possibly the growth of the epidermis is analagous to the growth of the cork cambium of plants, the stratum mucosum corresponding to the green cells and the stratum corneum to the corky layer of the cambium. If such be the case—and he insists that there is much evidence in support of it—the deeper cells would advance inwards towards the corium and the superficial cells would grow outwards towards the surface. Under this view the active layers would be the stratum granulosum and stratum lucidum, and by it many of the difficulties would be explained, including the mysterious disappearance of the pigment from the superficial layers; it would also afford a reasonable explanation of how it happens that, in old age, a negro's hair becomes white, while his skin retains its blackness.

Vessels and Nerves of the Skin.—The **arteries** form a plexus in the subcutaneous tissue, from which branches extend into the corium, where they supply the hair follicles and glands and form a second plexus under the papillæ, to which small loops are given. The **veins** and **lymphatics** commence in the papillæ, and, after forming a subpapillary plexus, open into their respective subcutaneous vessels.

The **nerves** of the skin vary in number in different parts of the body, being extremely numerous where the sense of touch is acute, *e.g.* on the palmar aspect of the terminal phalanges, while in the skin of the back, where the sensibility is less, they are fewer in number. They form a plexus in the corium, and either terminate amongst the cells of the epidermis or in special end organs named **tactile corpuscles**. Those ending in the epidermis form a rich subepithelial plexus,

from which delicate fibrils pass between the cells of the rete mucosum, where they become beaded, and end in rounded swellings or flattened discs—the **tactile discs** of Ranvier.

The **special end organs** are of three chief varieties (Fig. 538): (*a*) **Corpuscula bulboidea** (Krausii), found on the lips, glans penis, etc., and consisting of a connective tissue capsule enclosing a core of elongated and polygonal cells, amongst which the axis-cylinder of the nerve fibril becomes branched and its ramifications end in clubbed extremities. (*b*) **Corpuscula lamellosa** (Vateri and Pacini). These are small, oval bodies, with a long diameter of 2 to 3 mm., and are found in the subcutaneous tissue attached to the nerve trunks. They are very numerous on the digital nerves, but are present in many other situations, *e.g.* in the mesentery. Each possesses a sheath, consisting of a number of concentrically-arranged connective tissue lamellæ, covered by endothelium continuous with the perineurium. The central part of each corpuscle consists of a soft, almost homogeneous core. The nerve fibre passes along the centre of the stalk of the corpuscle, and, reaching the core, loses its medullary sheath, whilst its axis-cylinder passes into the core and becomes branched near its distal extremity, the branches ending in bulbous enlargements. (*c*) **Corpuscula tactus** (Meissneri). These are very numerous on the flexor aspect of the hands and feet, and especially so in the skin over the terminal phalanges; but they also exist in other parts of the body. They occupy certain of the papillæ of the corium, and are oval in shape, their long diameter in the hand being from 110 μ to 160 μ. They consist of a connective tissue capsule, which sends imperfect septa into the interior of the corpuscle. One or two nerve fibres perforate the capsule, either directly or after taking a spiral course around it; and losing, as a general rule, their medullary sheath, their axis-cylinders break up into fibrils, which end in globular or discoid enlargements.

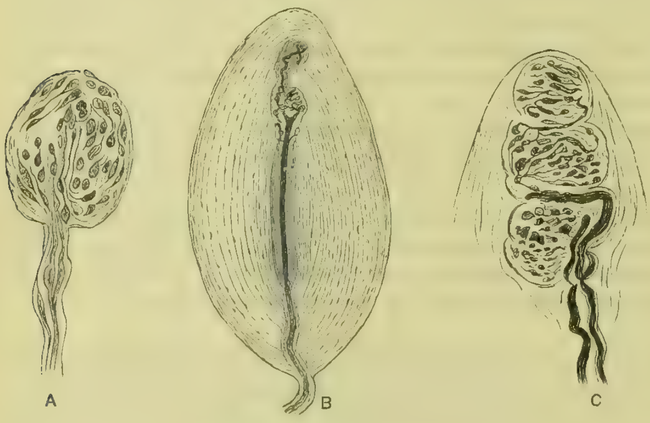


Fig. 538.—Tactile Corpuscles.

A, End bulb (Krause).
B, Corpuscle of Pacini } (after Ranvier).
C, Corpuscle of Meissner }

Ruffini has described a special variety of terminal corpuscle in the human finger. They are termed **Ruffini's endings**, and are situated either at the junction of the corium and subcutaneous tissue, or are embedded in the latter. Of an oval shape, they consist of a connective capsule within which the axis cylinder divides into varicose filaments, and these terminate in small knobs.

Appendages of the Skin.

The appendages of the skin comprise the nails, the hairs, the sebaceous and the sudoriparous or sweat glands.

Nails.—The nails or ungues (Figs. 539, 540) are epidermal structures, and, in man, represent the hoofs and claws of the lower animals. The **root** of the nail, or radix unguis, is hidden from view and embedded in a fold of skin; the **body** (corpus unguis) or uncovered part, rests on the corium and ends in a **free edge** or margo liber. The greater part of the lateral margins is overlapped by a duplicature of skin, termed the **nail-wall** or **vallum unguis**. The nails are pink in colour, with the exception of a small semilunar area near the root, which is more opaque than the rest and is named the **lunula**. The lunulæ diminish in size from the thumb towards the little finger, while the thickness of the nail diminishes towards its root and lateral margins. The corium under the nail is highly vascular and sensitive,

and presents, especially under the anterior part of the body, numerous longitudinally-arranged papillæ. The part of the corium under the body is termed the **nail**

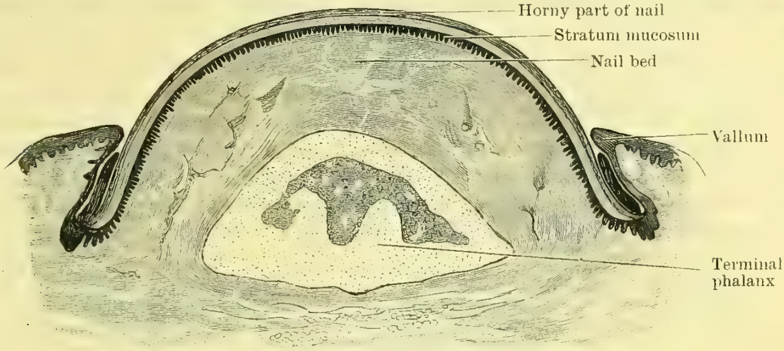


FIG. 539.—TRANSVERSE SECTION OF A NAIL.

bed; that under the root, the **nail matrix**. The deep part of the nail consists of the stratum germinativum and stratum mucosum, while its superficial horny portion is constituted by a greatly thickened stratum lucidum, and consists of nucleated, keratinised squames. The stratum corneum is represented by the thin cuticular fold overlapping the lunula, and termed the **eponychium**, while the stratum granulosum can only be traced as far forwards as the nail root.

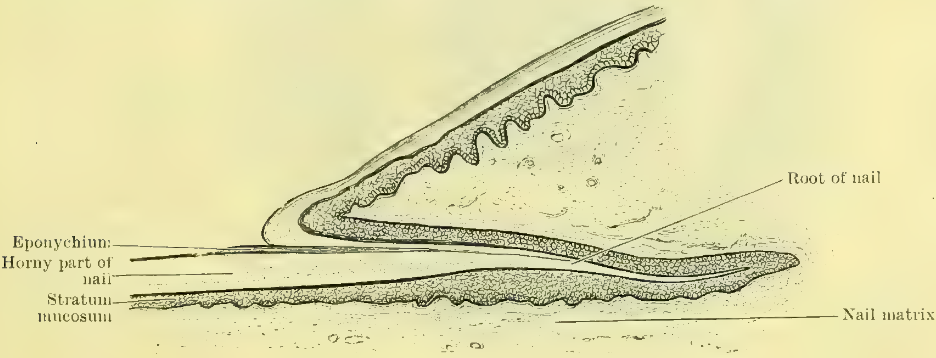


FIG. 540.—LONGITUDINAL SECTION THROUGH ROOT OF NAIL.

Hairs.—Hairs (pili) are well developed on the scalp, pubes, and margins of the eyelids, in the axilla, the vestibule of the nose, and at the entrance to the concha, and also on the face of the male. Those on the genitals and face appear about puberty. Rudimentary over the greater part of the body, they are entirely absent on the flexor surfaces of the hands and feet, over the dorsal aspect of the terminal phalanges, the glans penis, the inner surface of the prepuce, and inner aspect of the labia. Marked variations, individual and racial, exist as to the colour of the hair, and also as to the manner of its growth; hence the terms straight, curly, woolly, etc., are used to designate it. Straight hairs are coarser than curly ones, and have, moreover, a circular or oval outline on transverse section, curly hairs being flat and riband-like.

The **root of the hair** (radix pili) is embedded in a depression of the skin, termed the **hair follicle** (Fig. 536); while the free portion is named the **stem** or **shaft**, and consists from without inwards of three parts, viz. cuticle, cortex, and medulla. The *cuticle* is formed by a layer of imbricated scales which overlap one another from below upwards. The *cortex* consists of longitudinally-arranged fibres made up of elongated, closely-applied, fusiform cells, which contain pigment and sometimes air spaces, the latter especially in white hairs. The *medulla*, absent from the fine hairs of the body generally and from the hairs of young children, forms a central core, which appears black by transmitted and white by reflected light, and is composed of polyhedral nucleated cells containing pigment, fat granules, and air spaces.

The **hair follicle** (folliculus pili) consists of an oblique or curved—the latter in curly hairs—invagination of the epidermis and corium, and, in the case of large hairs, extends into the subcutaneous tissue (Fig. 536); some little distance below its orifice, the ducts of the sebaceous glands open into it. The portion of the follicle derived from the corium (dermic coat) consists of a fibrous sheath of external longitudinal and internal circular connective tissue fibres, the latter being lined by a hyaline layer directly continuous with the basement membrane of the corium. The parts of the follicle derived from the epidermis are named the **inner** and **outer root sheaths**. Below the orifices of the sebaceous gland ducts the outer root sheath is formed by the stratum germinativum and stratum mucosum, while above them all the epidermal strata contribute to it. The inner root sheath surrounds the cuticle

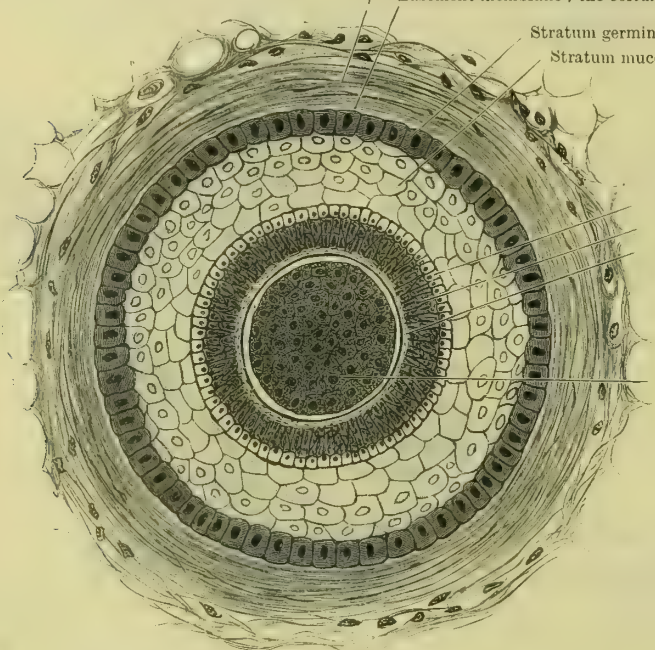


Fig. 541.—Transverse Section of Hair Follicle with contained Hair (highly magnified).

of the hair, and consists from without inwards of—(*a*) *Henle's layer*, a single stratum of nucleated, cubical cells; (*b*) *Huxley's layer*, a single or double layer of polyhedral nucleated cells; and (*c*) a *delicate cuticle*, consisting of a single layer of flattened imbricated cells, with atrophied nuclei. The bottom of the hair follicle is indented by a vascular **papilla** (papilla pili), derived from the corium and capped by the bulb (bulbus pili) or expanded part of the hair root. The cells of the bulb are continuous with those of the outer root sheath, and form the different parts of the hair, as well as its inner root sheath. The vessels form capillary loops in the papilla of the hair, and send twigs into the outer layer of its fibrous sheath; the inner and outer root sheaths and the different parts of the hair are non-vascular. The nerves terminate in longitudinal and annular fibrils below the level of the sebaceous glands and outside the hyaline layer of the follicle.

Sebaceous glands (glandulæ sebaceæ) exist wherever there are hairs, and their ducts open into the superficial part of the hair follicles (Fig. 536); the number of glands associated with each follicle varies from one to four. On the labia minora and mammary areolæ they open on the surface of the skin independently of hair follicles, and in the latter situation undergo great enlargement during pregnancy. The deep extremity of each gland expands into a cluster of oval or flask-shaped **alveoli**, which are surrounded by a basement membrane and filled with polyhedral cells containing oil droplets. By the breaking down of the superficial cells, their oily contents are liberated as the *sebum cutaneum* and discharged into the hair

follicle, whilst the deeper cells undergo proliferation. The size of the gland bears no proportion to that of the hairs, since they are very large in the minute hair follicles of the fœtus and newly born child, and also in the follicles of the rudimentary hairs of the nose and certain parts of the face.

Bundles of non-striped muscular fibre are associated with the hair follicles, and are named the **mm. arrectores pilorum.** Attached to the deep part of the hair follicle, and forming with it an acute angle, they pass outwards close to the sebaceous glands, to end in the papillary layer of the corium. Situated on the side of the hair towards which it slopes, they, on contraction, diminish the obliquity of the hair follicle and render the hair more erect, and, at the same time, compress the sebaceous glands and expel their contents. The condition of "goose-skin" is caused by the contraction of these slender muscles.

Thomson suggests that the condition of curly hair is produced by the contraction of these small muscles. Straight hair is thick and rounded; curly hair is flat and ribbon-like. When the erector muscle contracts, the thick rounded hair resists the tendency of the muscle to bend it, while the flat hair, not sufficiently strong to resist the strain of the muscle, becomes bent, and this is probably the explanation why the follicle assumes the curved form characteristic of the scalp of a bushman. The sebaceous gland lies in the concavity of the bend between the follicle and the muscle, and forms a mass of greater resistance, around which the follicle may be curved by the contraction of the muscle. The cells at the root of the hair accommodate themselves to the curved follicle, and, becoming more horny as they advance to the surface, retain the form of the follicle in which they are moulded.

The **sudoriparous** or **sweat glands** (glandulæ sudoriferæ) are relatively few in number on the back of the trunk, but are very plentiful on the palms and soles, where they open on the summits of the curved ridges. Each consists of an elongated tube, the deeper portion of which forms its secretory part and is coiled in the subcutaneous tissue or deep part of the corium in the form of an ovoid or spherical ball, termed the **glomerulus** or **corpus glandulæ sudoriferæ** (Fig. 536). The superficial part of the tube, or **ductus sudoriferus**, extends through the corium and epidermis, in which it is spirally coiled, if the epidermis be thick, and opens on the surface by a funnel-shaped orifice, the **porus sudoriferus.** The **glomeruli**, as a rule, vary in diameter from 0·1 to 0·5 mm., but in the axillæ they are much larger and may measure 1-4 mm. Each is surrounded by a capillary network and by a capsule of connective tissue, inside which is a homogeneous basement membrane. The lumen of the tube is lined by a layer of nucleated, granular, and striated, columnar, or prismatic epithelium, between the deep extremities of which and the basement membrane is a layer of non-striped muscular fibres, the long axis of which is more or less parallel to the long axis of the tube. The excretory ducts are devoid of muscular fibres, and consist of a basement membrane lined by two or three layers of polyhedral cells, which are covered, next the lumen of the tube, by a thin cuticle.

The **glands of Moll** (glandulæ ciliares), opening at the margins of the eyelids, and the **glandulæ ceruminosæ** of the external auditory meatus, are modified sudoriparous glands; the former are, however, not coiled up to form glomeruli, while the cell protoplasm of the latter contains yellowish pigment, and their gland ducts, in the fœtus, open into hair follicles.

Development of the Skin and its Appendages.

Skin.—The vascular and sensitive corium is developed from the mesoblast, the cells of which, immediately underlying the epiblast, have, by the second month of fœtal life, become aggregated together and flattened parallel to the surface of the embryo. By the third month they are seen to form two layers, the superficial of which becomes the corium, and the deeper the subcutaneous tissue. The epidermis, nails, hairs, sweat and sebaceous glands are all of epiblastic origin.

The epidermis at first consists of a single layer of cells, but by the end of the second month it is duplicated, and then exhibits a superficial layer of irregular and a deeper layer of more cubical cells. By the third month three strata are seen: (*a*) a deep layer, consisting of a single stratum of cubical cells—the future stratum germinativum; (*b*) a middle layer, comprising two or three strata of irregular cells—the future stratum mucosum; and (*c*) an outer layer, a double stratum of large cells. This outer layer

appears to be homologous with a thin membrane, termed the *epitrichium*, first described as covering the embryo of the sloth and overlying its hairs, but since shown to be present in birds and mammals. Over the hairy parts of the body it ultimately disappears; but over the free edge and root of the nails, and on the palms and soles, it develops into several layers of cells, which, in these parts, probably persist to form the thick stratum corneum. The part which persists over the root of the nail is termed the *eponychium*, and covers the proximal part of the lunula (*vide* p. 731). The stratum lucidum is differentiated from the cells of the epitrichium, and, where the latter is lost, possibly forms the superficial layer of the epidermis as it does the horny part of the nails.

Nails.—The first rudiment of the nails is seen about the beginning of the third month of embryonic life, and consists of a thickening of the epitrichium over the extremity of the digits. Owing to the growth of the palmar aspect of the digits, the nail rudiment comes to be placed dorsally, and, at its proximal edge, an ingrowth of the stratum mucosum occurs to form its root, while the future nail becomes limited behind and laterally by a groove. The superficial cells of the stratum mucosum become keratinised to form a thick stratum lucidum, the future nail proper, over the greater part of which the epitrichium disappears. The latter persists in the adult as the eponychium, and, until the fifth month, also forms a thick mass over the extremity of the nail, and is continued into the stratum corneum over the end of the digit. The future distal edge of the nail, at this stage, is continuous with the stratum lucidum in front of it; but ultimately this continuity is lost and the edge becomes free. The nails grow in length, and are renewed, in case of removal, by a proliferation of the cells of the stratum mucosum at the root of the nail, while an increase in their thickness takes place from the part of the same stratum which underlies the lunula.

Hairs.—The hair rudiments appear about the third month of embryonic life as solid downgrowths of the stratum mucosum, which pass obliquely into the subjacent corium. The deep end of this column of cells becomes expanded to form the hair bulb, and rests on a papilla derived from the corium, the epidermis immediately overlying which becomes differentiated into the hair and its inner root sheath, while the peripheral cells form its outer root sheath. The surrounding corium becomes condensed to form the fibrous sheath of the hair follicle, the hyaline layer of which is continuous with the basement membrane covering the corium. The hair gradually elongates, and, reaching the neck of the follicle, its extremity lies at first under the epitrichium, but becomes free on the disappearance of the latter. This takes place about the fifth month, and the first crop of hairs constitutes the *lanugo*, which is well developed by the seventh month. The lanugo consists of very delicate hairs, some of which are shed before, the remainder shortly after birth—the last to drop out being those of the eyelashes and scalp—and are replaced by stronger hairs. Shedding and renewal of the hairs take place during life, the renewal being of course absent in the case of baldness. Prior to the shedding of a hair, active growth and proliferation of the cells of the hair bulb cease and the papilla becomes atrophied, while the hair root, gradually approaching the surface, at last drops out. New hairs arise from epidermic buds, which extend downwards from the follicle, and their development is identical with that of the original hairs.

Sebaceous Glands.—These appear about the fifth month as solid outgrowths from the sides of the hair follicles, and consist of epidermal offshoots continued from the cells of the outer root sheath. Their deep ends become enlarged and lobulated, to form the secreting part of the gland, while the narrow neck connecting this with the follicle forms its duct. The sebaceous secretion, together with the cast-off epidermal cells, is collected on the surface of the body during the last months of intrauterine life, and forms a layer of varying thickness, termed the *vernix caseosa* or *smegma embryonum*.

Sweat Glands.—These, like the hairs, arise as solid downgrowths of the stratum mucosum. They descend, however, perpendicularly, instead of obliquely, and are of a yellowish colour; they appear on the palms and soles early in the fifth month, but much later over the hairy parts of the body. The downgrowths extend through the corium, and, on reaching the subcutaneous tissue, become coiled up to form the secreting part of the gland. The lumen of the gland does not open on the surface until the seventh month.

THE VASCULAR SYSTEM.

By Alfred H. Young and Arthur Robinson.

The vascular system consists of a series of tubular vessels, with more or less distinct walls, which run through all parts of the body. Some contain blood, others are filled with a colourless fluid called lymph; hence the distinction between the blood-vascular system and the lymph-vascular system. The two systems differ, not only as regards their contents, but also in their relations to the tissues amongst which they lie; for whilst the vessels of the former system are closed, those of the latter communicate freely with intercellular spaces and serous sacs.

The **blood-vascular system** is tubular throughout; the tubes or vessels possess distinct walls; they vary in size and in the structure of their walls, but all contain blood, which is conveyed through them to and from the tissue elements of the body. The blood is propelled along the vessels chiefly by a central propulsive organ—the **heart**. The outgoing vessels from the heart, along which blood is transmitted to the tissues, are termed **arteries**; the vessels which return blood from the tissues to the heart are known as **veins**; whilst the smallest tubes—those which connect the arteries and veins together, constituting at once the terminations of the arteries and the commencements of the veins—are called **capillaries.**

Blood capillaries are very small (hair-like) vessels with exceedingly thin walls, which permit of the easy passage outwards of the nutritive plasma from the blood to the tissues, and, in the opposite direction, of some of the products of tissue changes as well as of modified food material from the alimentary canal.

Arteries and veins are simply conducting passages; structurally they differ from capillaries in the greater complexity of their walls. They vary greatly in size, but are always larger than capillaries, and they grow larger and larger the nearer they are to the heart. With increase in size there is a corresponding increase in the thickness and complexity of their walls.

Structure of Blood Capillaries.—Capillaries measure from $\frac{1}{3000}$ to $\frac{1}{2000}$ of an inch in diameter, and about $\frac{1}{25}$ to $\frac{1}{20}$ of an inch in length. Their walls are simple, and, in the smallest capillaries, consist principally of elongated elastic endothelial cells, with sinuous edges, pointed extremities, and oval nuclei. The cells are cemented to one another along their margins by intercellular cement, which readily stains with nitrate of silver. Here and there the cement substance appears to accumulate, forming minute spots indicative of the less perfect apposition of the edges of the cells. These spots, when small, form the so-called **stigmata**; when larger they are known as **stomata.**

The larger capillaries are invested by a connective tissue sheath consisting of branched cells which are united together and to the endothelial cells of the capillary wall. This sheath is termed the **adventitia capillaris.**

Capillaries are arranged in networks, the nature and character of which differ in different tissues. The small arteries which end in them are known as **capillary arterioles**, and the venous radicles which commence from them are appropriately termed **capillary veins.**

Structure of arteries and veins.—The delicate elastic endothelial membrane forming the wall of the simplest capillaries extends as a continuous lining throughout the whole of the blood-vascular system. The constituent cells are fusiform,

narrow and pointed in the arteries, whilst in the veins they are somewhat shorter and broader.

The most essential structural difference between capillaries and the arteries and veins which they unite together, is to be found in the presence, in both of the latter, of involuntary muscular fibres interposed between the endothelial lining and the outer connective tissue sheath. In small vessels, *e.g.* capillary arterioles, the muscle cells are few in number and more or less scattered. In larger vessels the walls become stronger and thicker, muscular fibres increase and form a continuous layer, whilst yellow elastic and ordinary white connective tissue are added in varying proportions. The walls of the vessels thus become more complex, and numerous strata may be distinguished; these, however, are for convenience regarded as forming three layers, which are known as the inner, middle, and outer coats, superadded to which is the investing common sheath.

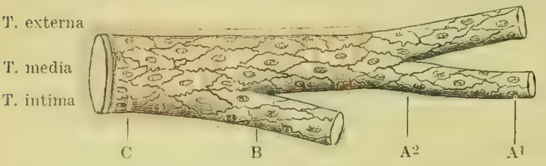


FIG. 542.—STRUCTURE OF BLOOD VESSELS (Diagrammatic.)

A^1, Capillary—with simple endothelial walls. A^2, Larger capillary—with connective tissue sheath, "adventitia capillaris." B, Capillary arteriole—showing muscle cells of middle coat, few and scattered. C, Artery—muscular elements of the tunica media forming a continuous layer.

Structure of Arteries.—The walls of arteries are stronger and thicker than those of veins of corresponding size, the inner and middle coats being respectively particularly rich in elastic and muscular elements.

Inner coat (tunica intima).—The simple endothelial layer of the arterioles is strengthened by the addition of yellow elastic tissue, which usually forms a fenestrated membrane, but sometimes consists of longitudinal fibrils. In arteries of medium size the elastic lamina is separated from the endothelium by a layer of connective tissue consisting of branched cells and numerous fibrils. In the larger arteries the sub-endothelial connective tissue is considerably increased, and delicate elastic fibres appear which connect it with the more externally situated fenestrated elastic layer.

The **middle coat** (tunica media) in the capillary arterioles consists solely of scattered unstriped muscle fibres; the individual fibres are circularly disposed, but do not entirely surround the vessel. In small arteries the muscle cells are so far increased in amount that they form a continuous though thin layer. As the arteries increase in size additional layers of muscle cells are added, and the greater thickness of the arterial wall is mainly due to this increase of the muscular elements of the middle coat. In the larger vessels delicate laminæ of elastic tissue alternate with the layers of muscular fibres, and in the aorta and the carotid arteries, as well as in some of the branches of the latter, the elastic elements largely preponderate. In the first part of the aorta, in the pulmonary artery, and in the arteries of the retina, the muscular fibres are entirely replaced by elastic tissue.

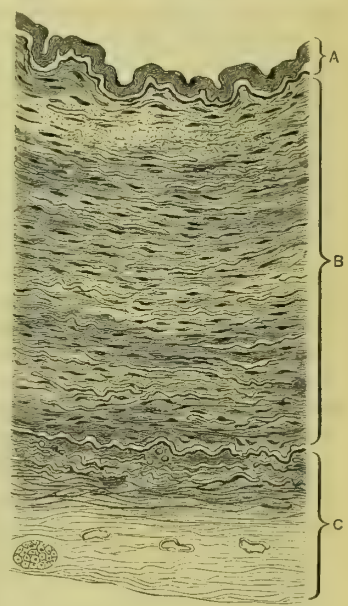


FIG. 543.—TRANSVERSE SECTION THROUGH THE WALL OF A LARGE ARTERY.

A, Tunica intima. B, Tunica media. C, Tunica externa.

The **external coat** (tunica externa) of an artery consists almost entirely of fibrillated connective tissue, with connective tissue corpuscles lying in corresponding spaces. In all but the smallest arteries numerous elastic fibres are also present. The elastic element is specially strong near the middle coat in small and medium-sized vessels, and is sometimes described as the external elastic membrane of Henle. In some arteries longitudinally arranged unstriped muscular fibres are also found in the external coat.

The **sheath of an artery** (vagina vasis).—In addition to the three coats above described, arteries are enclosed in a sheath of the surrounding connective

tissue, and are more or less connected with it by fine strands of fibrillated connective tissue.

Structure of veins.—The walls of veins are similar in structure to those of arteries; they are, however, thinner, so much so that, although veins are cylindrical tubes when full of blood, they collapse when empty and their lumina almost disappear. The structural details of the three coats vary somewhat in different veins; in most the inner coat is marked by folds which constitute valves. Like the arteries, the veins are enclosed in connective tissue sheaths.

The **inner coat** (tunica intima).—In the majority of the veins the inner coat includes an internal endothelial layer, a middle layer of sub-endothelial connective tissue, and an outer layer of elastic tissue. The inner coat of a vein is less brittle than the inner coat of an artery, and is more easily peeled off from the middle coat. The sub-endothelial tissue is a fine fibrillated connective tissue, less abundant than in the arteries, and indeed in many cases it is absent. The elastic layer consists of lamellæ of elastic fibres which are arranged longitudinally, and it rarely forms a fenestrated membrane.

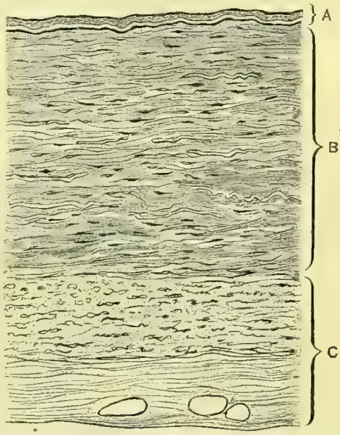


FIG. 544.—TRANSVERSE SECTION OF THE WALL OF A VEIN.
A, Tunica intima. B, Tunica media. C, Tunica externa.

One of the chief peculiarities of the inner coat is the presence of folds of its substance which constitute **valves.** The valves are of semilunar shape, and they are usually arranged in pairs. Their convex borders are continuous with the vessel wall, and their free borders are turned towards the heart; whilst, therefore, they do not interfere with the free flow of blood onwards, they prevent any backward flow towards the periphery, and they help to sustain the column of blood in all vessels in which there is an upward flow. Each valve consists of a fold of the inner or endothelial layer, strengthened by a little connective tissue. As a general rule, the wall of the vein is dilated above each valve into a shallow pouch or sinus; consequently, when the veins are distended they assume a nodulated appearance.

The **middle coat** (tunica media) is much thinner than the corresponding coat of an artery, and it contains a smaller amount of muscular and a larger amount of ordinary connective tissue; indeed, so much does the latter preponderate that it separates the muscular fibres into a number of bands isolated from each other by strands of connective tissue, and the muscle fibres do not form a continuous layer. In some of the veins the more internal muscular fibres do not retain the transverse direction which is usually met with both in arteries and veins; on the contrary, they run longitudinally. This condition is met with in the branches of the mesenteric veins, in the femoral and iliac veins, and in the umbilical veins. The middle coat is absent in the thoracic part of the inferior vena cava; it is but slightly developed in many of the larger veins, whilst in the jugular veins its muscular tissue is very small in amount.

The **external coat** (tunica externa).—This coat consists of white fibrous and elastic tissue. In many of the larger veins a considerable amount of muscular tissue is also present; this is the case in the iliac and axillary veins, the abdominal part of the inferior vena cava, the azygos veins, and in the renal, spermatic, splenic, superior mesenteric, portal, and hepatic veins. The external coat is frequently thicker than the middle coat, and the two are not easily separable from one another.

Vascular and Nervous Supply of arteries and veins.—Blood-vessels.—The walls of the blood-vessels are supplied by numerous small arteries, called *vasa vasorum*, which are distributed to the outer and middle coats. They arise either from the vessels they supply or from adjacent trunks, and after a short course enter the walls of the vessels in which they end. The blood is returned by correspondingly small veins.

Lymphatics.—Although the cell spaces in the middle and inner coats may be

regarded as the commencement of lymphatics, definite lymphatic vessels are limited to the outer coat.

Nerves.—Arteries and veins are well supplied with both medullated and non-medullated nerve fibres. The fibres form dense plexuses on the outer surfaces of the vessels, from which filaments pass to the middle coat to be distributed almost entirely to its muscular fibres.

Divisions of the blood-vascular system.—Blood-vessels convey blood to or from the tissues of the body generally, or to and from the lungs. The former constitute the **systemic vessels** or **general system**; the latter form the **pulmonary system.** These two systems are connected together by the heart.

The venous trunks passing to the liver form a subsidiary part of the general systemic group of vessels, which is known as the **portal system.**

THE HEART.

The **heart** (cor) is a hollow muscular organ, and is enclosed in a fibro-serous sac known as the pericardium. It receives blood from the veins, and propels it into and along the arteries. The cavity of the fully-developed heart is completely separated into right and left halves by an obliquely-placed longitudinal septum, and each half is divided into an upper receiving chamber, the **auricle**, and a lower ejecting chamber, the **ventricle.** The separation of the auricle from the ventricle, however, is not complete. Externally a comparatively shallow constriction, running transversely to the long axis of the organ, indicates the distinction between the auricles and ventricles; internally a wide aperture is left between the auricle and ventricle of each side. Each **auriculo-ventricular aperture** is provided with a valve which allows the free passage of blood from the auricle to the ventricle, but effectually prevents its return.

It has already been pointed out that the delicate walls of the blood capillaries allow of the free passage outwards of nutritive plasma from the blood. It passes into spaces, or intercellular channels, in which the tissue elements lie; thus the latter are directly bathed in blood plasma. The intercellular spaces form the commencement of the lymph-vascular system. They communicate together, and open into lymph-vessels which carry the used plasma back to the blood-vascular system, but in addition they also convey new nutritive material, the product of digestive processes, from the alimentary canal.

Lymph-vessels, in other words, convey material from the tissues. Blood-vessels convey material both to and from the tissues.

The removal of waste products from the blood is provided for by special organs, some of which are simply interposed in the course of the general circulation—*e.g.* the liver, the kidneys, and the skin. The lungs, however, where the impure or venous blood receives its main supply of oxygen and gives up most of its carbonic oxide, etc., do not lie in the course of the general or systemic circulation, and a secondary or pulmonary circulation is established, by which venous blood is conveyed from the heart to the lungs by the pulmonary artery and its branches, and, after passing through the pulmonary capillaries, is returned again to the heart, as pure arterial blood, by the pulmonary veins.

The heart, anatomically a single organ, is correspondingly modified, and, as described above, it is divided into a left part, the **systemic heart**, and a right part, the **pulmonary heart.** It receives on its right side the blood from the systemic veins, which it ejects into the pulmonary artery; whilst on its left side it receives blood from the pulmonary veins, and ejects it into the main systemic artery—the aorta.

The **shape** of the heart is that of an irregular and somewhat flattened cone; and a base, an apex, two surfaces (inferior and antero-superior), and two borders (right and left) are distinguishable.

An oblique groove—the **auriculo-ventricular groove** (sulcus coronarius)—runs transversely to the long axis of the organ, and separates the upper auricular portion from the lower ventricular part. The separation of the auricular portion into right and left chambers is only marked externally at the base of the heart, where an indistinct interauricular groove exists. The division of the lower part into right and left ventricles is more definitely marked on the surface by anterior and inferior interventricular sulci (sulci longitudinales).

Enclosed in the pericardium, which accordingly intervenes between it and the

neighbouring structures, the heart lies in the middle mediastinum, and rests below on the diaphragm. Its long axis, from base to apex, runs obliquely from behind forwards, downwards, and to the left.

The *base* (basis cordis), formed entirely by the auricles, and almost entirely by the left auricle, is directed upwards, backwards, and to the right. It lies in front of the descending thoracic aorta, the œsophagus, and the lower right pulmonary vein, which separate it from the bodies of the fifth, sixth, seventh, and eighth dorsal vertebræ.

On the whole the base is somewhat flattened, and it is irregularly quadrilateral in form. It presents the orifices of the superior and inferior venæ cavæ and the four pulmonary veins. The opening of the superior vena cava is situated at the upper right angle, that of the inferior cava occupies the lower angle on the right side;

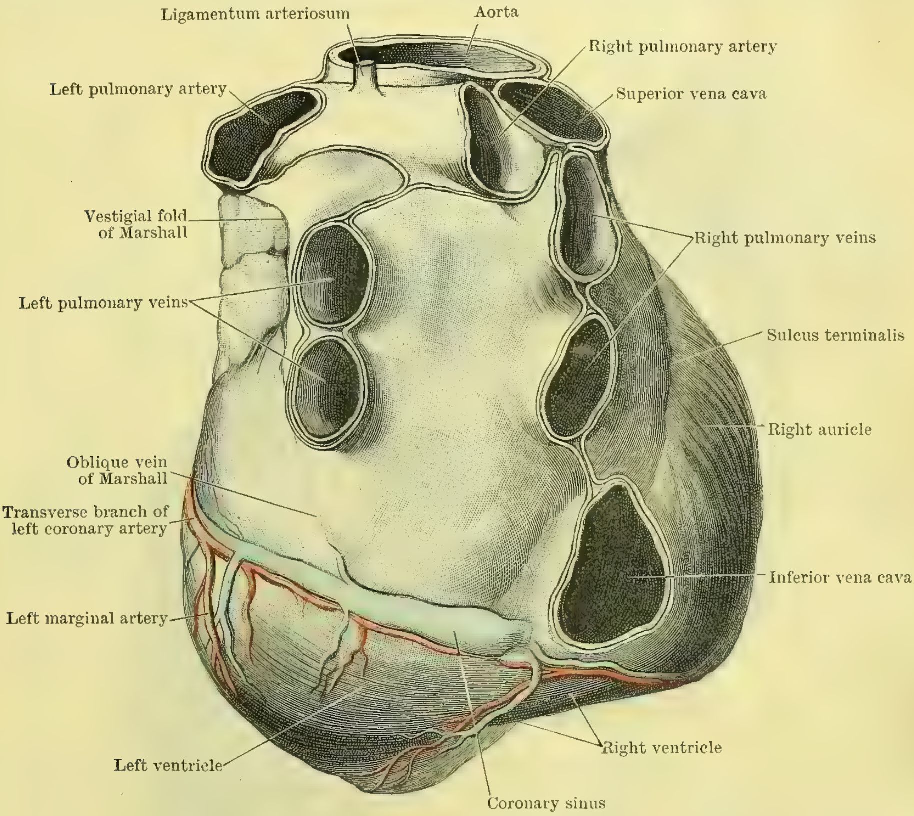


FIG. 545.—THE BASE AND INFERIOR SURFACE OF THE HEART, showing the openings of the great vessels and the line of reflection of the serous pericardium.

between these are the orifices of the two right pulmonary veins, and immediately to the right of the latter is the indistinct posterior interauricular sulcus, which descends to the left of the orifice of the inferior vena cava. The openings of the two left pulmonary veins are situated near the left border of the base; and the portion of the surface which lies between the right and left pulmonary veins forms the anterior boundary of the great oblique sinus of the pericardium.

The base is limited below by the lower part of the auriculo-ventricular groove, in which the coronary sinus lies; its upper border is in relation with the bifurcation of the pulmonary artery. A fold of pericardium, the vestigial fold of Marshall (ligamentum v. cavæ sinistræ) descends, near the left border of the base, from the left branch of the pulmonary artery above to the left superior pulmonary vein below; and from the lower end of this fold, crossing obliquely below the left pulmonary vein to reach the coronary sinus, is the small oblique vein of Marshall (v. obliqua atrii sinistri [Marshalli]). Further, it is from the base that the visceral layer of the pericardium which elsewhere completely invests the heart

is reflected, the lines of reflection corresponding with the orifices of the great vessels.[1]

The *apex* (apex cordis), bluntly rounded, is formed entirely by the left ventricle. It is directed downwards, forwards, and to the left, and is situated, under cover of the anterior border of the left lung and pleura, behind the fifth left intercostal space, three and a-quarter inches from the anterior mesial line.

The *inferior surface* (facies diaphragmatica) is formed by the ventricular part of the heart. It rests upon the diaphragm, chiefly on the central tendon, but, upon the left side, on a small portion of the muscular substance also, and it is divided into two areas—a smaller to the right side and a larger to the left side—by an oblique antero-posterior groove, the **inferior interventricular sulcus.** It is separated from the base by the posterior or inferior portion of the auriculo-ventricular sulcus.

The *antero-superior surface* (facies sterno-costalis) is directed upwards, for-

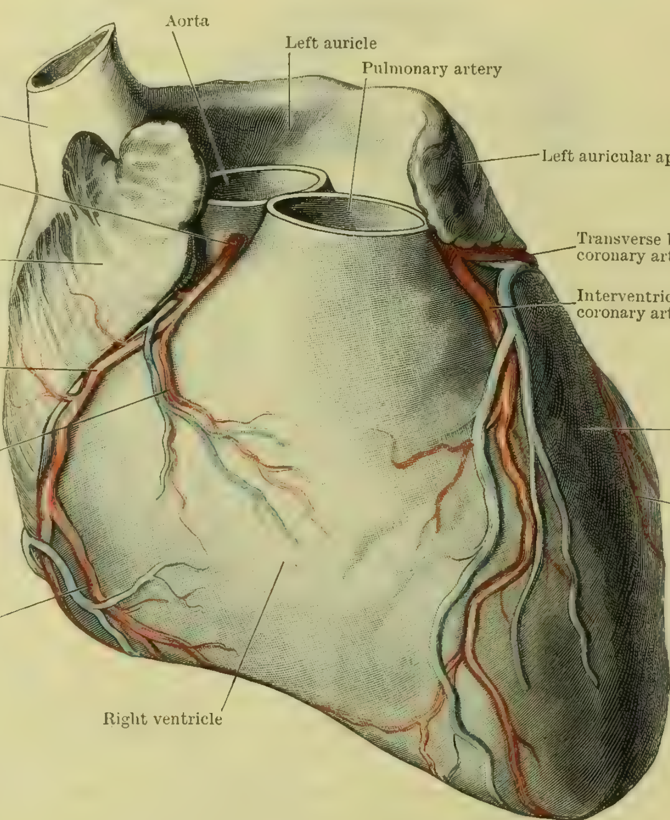


FIG. 546.—THE ANTERO-SUPERIOR SURFACE OF THE HEART.

wards, and to the left. It lies behind the body of the sternum and the inner extremities of the cartilages of the third, fourth, fifth, and sixth ribs on the right side, and a greater extent of the corresponding cartilages on the left side. This surface is separated into upper and lower sections by the anterior portion of the auriculo-ventricular groove, which runs obliquely from above downwards, and from left to right, from the level of the third left to that of the sixth right costal cartilage. The upper section of the surface, which is concave, is formed by the auricles; it is separated from the sternum by the roots of the aorta and the pulmonary artery, and is continuous laterally with the auricular appendices which, projecting forwards embrace these great vessels. The lower section of the antero-superior surface is convex; it is formed by the ventricular part of the heart, and is divided by an anterior interventricular sulcus into a smaller left and a larger right

[1] In the fœtus and young child the auricular portion of the heart forms not only the base, but also the posterior part of the inferior or diaphragmatic surface.

part. At the junction of the auricular and ventricular parts of this surface are the orifices of the pulmonary artery and the aorta, the former lying in front of the latter.

The *right margin* of the heart consists of an upper auricular part and a lower ventricular part. The former is almost vertical; it lies behind the cartilages of the third, fourth, fifth, and sixth ribs on the right side about half an inch from the margin of the sternum; it is in relation with the right pleura and lung, the phrenic nerve with its accompanying vessels intervening, and it is marked by a shallow groove—the sulcus terminalis—which passes from the front of the superior vena cava to the left of the inferior vena cava. The lower part of the right margin (margo acutus) is sharp, thin, and usually concave, corresponding with the curvature of the anterior part of the diaphragm: it is formed by the right ventricle, and it lies almost horizontally in the angle between the diaphragm and the anterior wall of the thorax, passing from the sixth right costal cartilage behind the lower part of the body of the sternum, or the ensiform cartilage, and behind the cartilages of the sixth and seventh ribs on the left side to the apex of the heart.

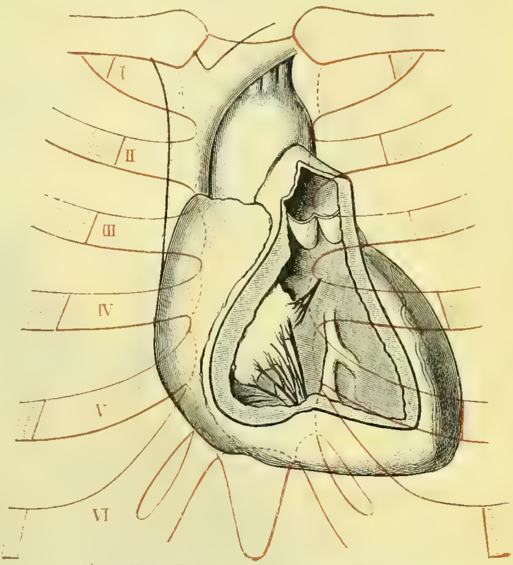


FIG. 547.—THE RELATION OF THE HEART TO THE ANTERIOR WALL OF THE THORAX.

I, II, III, IV, V, VI, the upper six costal cartilages.

The *left margin* (margo obtusus) is formed mainly by the left ventricle, and only to a small extent by the left auricle. It is thick and rounded. It lies in relation with the left pleura and lung, the phrenic nerve and its accompanying vessels intervening, and it passes from just above the third left costal cartilage, about an inch from the sternum, to the apex of the heart, descending obliquely and with a convexity to the left.

THE CHAMBERS OF THE HEART.

Auricles (auricula cordis).—The auricular or basal portion of the heart is cuboidal in form. Its long axis, which lies transversely, is curved, with the concavity of the curve forwards. It is divided into two chambers—the right and left auricles—by a septum which runs from the front backwards and to the right, so obliquely that the right auricle lies in front and to the right, and the left auricle behind and to the left.

Each auricle is also somewhat cuboidal in form, the long axis of the right auricle, however, being directed antero-posteriorly, whilst that of the left auricle lies vertically, and each chamber possesses a well-marked, ear-shaped, forward prolongation, which projects from the anterior and upper angle and is known as the **auricular appendix**.

The **right auricle** (atrium dextrum) receives, posteriorly, the superior vena cava above and the inferior vena cava below. Between these, and a little above its middle, it is crossed posteriorly by the lower right pulmonary vein. It is continuous below and in front with the right ventricle at the auriculo-ventricular aperture. Above and in front it is in relation with the ascending aorta, and from the junction of this aspect with the right lateral boundary the right auricular appendix is prolonged forwards. On the right side it forms the upper portion of the right margin of the heart, and is in relation with the right phrenic nerve and its accompanying vessels, and with the right pleura and lung, the pericardium intervening.

On the left the auricle is limited by the oblique septum which separates it from the left auricle. The **sulcus terminalis** is a shallow groove on the surface of the right auricle, which passes from the front of the superior vena cava to the left of the inferior vena cava, and indicates the junction of the primitive sinus venosus with the auricle proper.

The interior of the auricle is lined with a glistening membrane, the **endocardium**; its walls are smooth, except anteriorly and in the auricular appendix where muscular bundles form a series of small vertical columns, the **musculi pectinati**. These terminate above in a crest, the **crista terminalis**, which corresponds in position with the sulcus terminalis externally.

At the upper and back part of the cavity is the opening of the superior vena cava, devoid of a valve. At the lower and back part is the orifice of the inferior vena cava, bounded in front by the rudimentary Eustachian valve; and immediately below the Eustachian valve, between it and the auriculo-ventricular orifice,

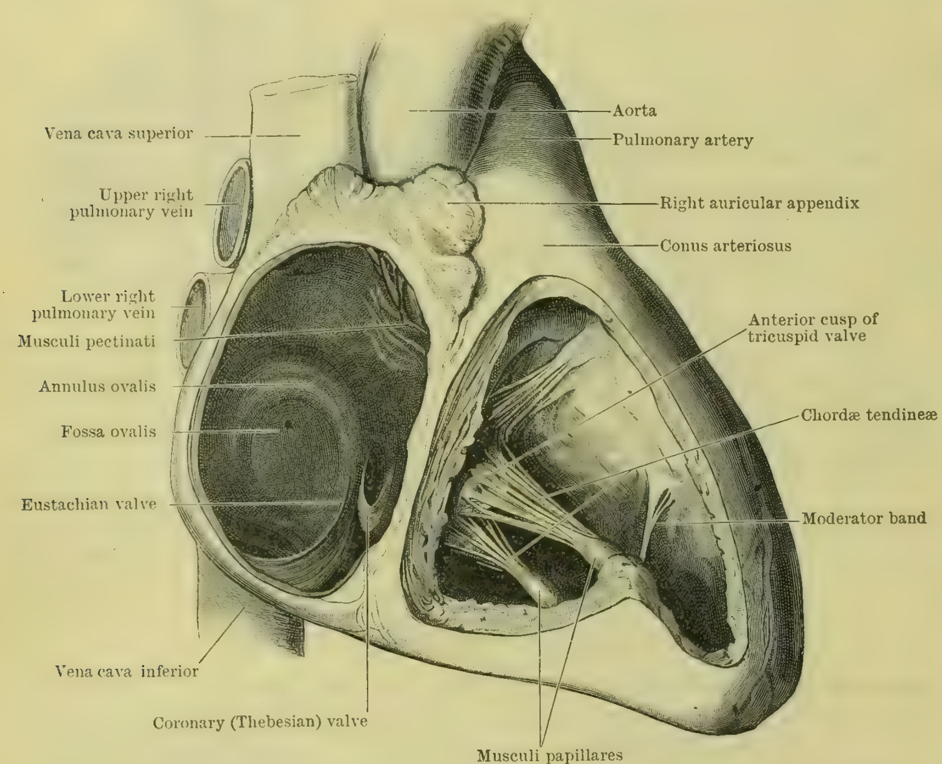


Fig. 548.—The Cavities of the Right Auricle and Right Ventricle of the Heart.

is the opening of the coronary sinus, guarded by the Thebesian valve. The auriculo-ventricular aperture, guarded by a tricuspid valve, is known as the **tricuspid orifice**. It is situated in the antero-inferior boundary, and admits three fingers. A number of small fossæ, **foramina Thebesii** (foramina venarum minimarum), are scattered over the walls, and some of these present at their apices the apertures of small veins, the **venæ minimi cordis**. In the septal wall is an oval depression, the **fossa ovalis**, bounded above and in front by a raised margin, the **annulus ovalis** (limbus fossæ ovalis), which is continuous inferiorly with the Eustachian valve; this fossa is the remains of an aperture, the **foramen ovale**, through which the two auricles communicated with each other before birth, and even in the adult a portion of the aperture persists at the upper part of the fossa in about one in five cases. Between the apertures of the superior and inferior venæ cavæ, and behind the upper part of the fossa ovalis, a small eminence may be distinguished, which is called the **tubercle of Lower** (tuberculum intervenosum); in the fœtus it probably directs the blood from the superior vena cava to the tricuspid orifice.

The **Eustachian valve** (valvula venæ cavæ inferioris) is a thin and sometimes fenestrated fold of endocardium and sub-endocardial tissue, which extends from the anterior and lower margin of the orifice of the inferior vena cava to the anterior part of the annulus ovalis. Varying very much in size, it is usually of falciform shape, its apex being attached to the annulus and its base to the margin of the inferior caval orifice. It is an important structure in the fœtus, directing the blood from the inferior vena cava through the foramen ovale into the left auricle.

The **Thebesian valve** (valvula sinus coronarii) is usually a single fold of endocardium which is placed at the orifice of the coronary sinus; occasionally it consists of two cusps. It is almost invariably incompetent.

The **left auricle** (atrium sinistrum) is in relation behind with the descending thoracic aorta and the œsophagus. Below and in front it is continuous with the left ventricle. Its antero-superior surface is concave, and lies in close relation to the roots of the ascending aorta, the pulmonary artery, and the left coronary artery. Its right side, formed by the interauricular septum, is directed forwards and to the right. Its left side forms a very small portion of the left margin of the heart, and from its junction with the antero-superior surface the long and narrow

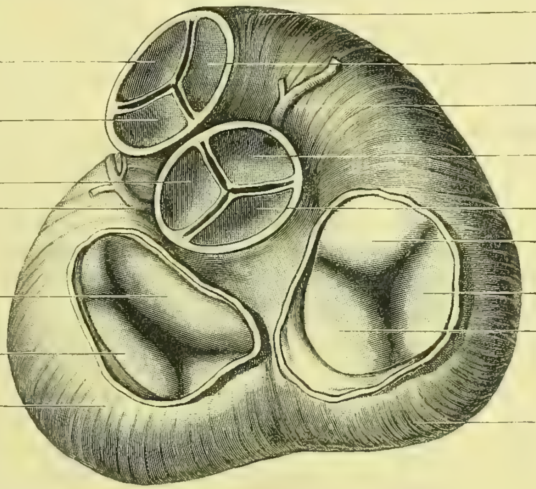


FIG. 549.—THE BASES OF THE VENTRICLES OF THE HEART, showing the auriculo-ventricular, aortic, and pulmonary orifices and their valves.

auricular appendix is prolonged forwards round the left side of the ascending portion of the aorta and the trunk of the pulmonary artery.

The four pulmonary veins enter the upper part of the posterior surface, two on each side.

The interior of the left auricle is lined with endocardium, and its walls are smooth, except in the auricular appendix where musculi pectinati are present, and on the septum, in a position corresponding with the upper part of the fossa ovalis on the right side, where there are several musculo-fibrous bundles radiating forwards and upwards. These septal bundles are separated at their bases by small semilunar depressions, in the largest of which remains of the foramen ovale may be found. Foramina Thebesii, and the apertures of venæ minimi cordis, are scattered irregularly over the inner aspect, whilst in the antero-inferior boundary is the auriculo-ventricular aperture. This is oval in form; its long axis is placed obliquely from before backwards, and from left to right, and is capable of admitting two fingers. It is guarded by a valve formed of two large cusps, and is known as the **mitral orifice**.

Ventricles.—The ventricular portion of the heart is conical and somewhat flattened. The base, directed upwards and backwards, is partly continuous with the auricular portion and partly free. It is perforated by four orifices, the two auriculo-ventricular, the aortic, and the pulmonary. The auriculo-ventricular

orifices are placed one on each side below and behind; in front and between them is the aortic orifice, whilst the orifice of the pulmonary artery is still farther forward, and slightly to the left of the aortic.

In the triangle (trigona fibrosa) between the auriculo-ventricular and the aortic orifices is embedded the central fibro-cartilage, a mass of fibro-cartilaginous tissue which is the representative of the os cordis of the ox. It is continuous with the upper part of the interventricular septum, and with fibrous rings which surround the apertures at the bases of the ventricles.

The apex of the ventricles forms the **apex** of the heart. The inferior surface and the antero-superior surface constitute respectively the greater portions of the corresponding surfaces of the heart; the former rests upon the diaphragm, whilst the latter is directed upwards and forwards towards the sternum and the costal cartilages of the left side.

The right margin, which is thin, forms the horizontal portion of the right margin of the heart; and the left margin, which is thick and rounded, forms almost the whole of the left margin of the heart.

The ventricular portion of the heart is divided into right and left chambers. The **interventricular septum** (septum ventriculorum) is placed obliquely, with one surface directed forwards and to the right, and the other backwards and to the left; it bulges into the right ventricle, and its lower margin lies to the right of the apex of the heart, which is, therefore, formed entirely by the left ventricle. The margins of the septum are indicated on the surface by anterior and inferior interventricular sulci.

The **right ventricle** (ventriculus dexter) is triangular in form. Its base is directed upwards and to the right, and in the greater part of its extent it is continuous with the right auricle, with which it communicates by the auriculo-ventricular orifice; but its left and anterior angle projects in front of the auricle, and gives origin to the pulmonary artery. Its inferior wall rests upon the diaphragm. The antero-superior wall lies behind the lower part of the left half of the sternum and the cartilages of the fourth, fifth, and sixth ribs of the left side. The left or septal wall, which is directed backwards and to the left, bulges into its interior, and on this account the transverse section of the cavity has a semilunar outline. The cavity itself is separable into two parts—a right or posterior portion, the **body**, into which the auriculo-ventricular orifice opens, and a left or anterior portion, the **infundibulum** or **conus arteriosus**, which terminates in the pulmonary artery. The two sections of the cavity are separated above by a thick fold of muscle, but otherwise they are quite continuous with each other.

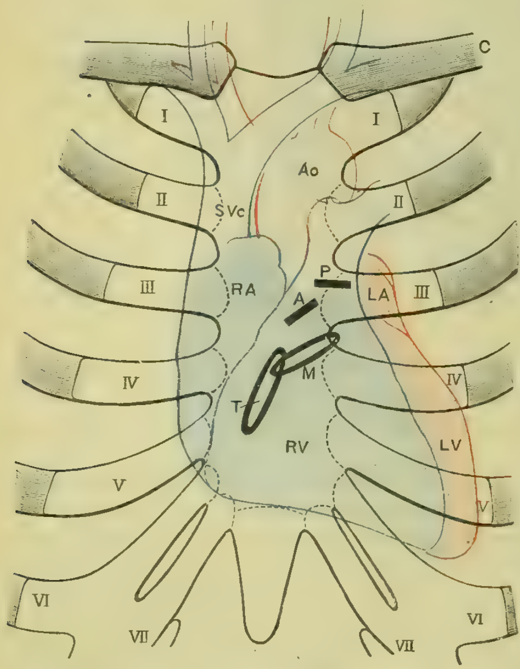


FIG. 550.—THE RELATIONS OF THE HEART AND THE AURICULO-VENTRICULAR, AORTIC, AND PULMONARY ORIFICES TO THE ANTERIOR THORACIC WALL.

I to VII, Costal cartilages.
A, Aortic orifice.
Ao, Aorta.
C, Clavicle.
LA, Left auricle.
LV, Left ventricle.
M, Mitral orifice.
P, Pulmonary orifice.
RA, Right auricle.
RV, Right ventricle.
SVc, Superior vena cava.
T, Tricuspid orifice.

The **right auriculo-ventricular orifice** is guarded by a **tricuspid valve** (valvula tricuspidalis). The three cusps of this valve are a right or marginal (cuspis medialis), a left or infundibular (cuspis anterior), which intervenes between the auriculo-ventricular orifice and the infundibulum, and a posterior or septal (cuspis posterior). Each cusp

consists of a double fold of endocardium, strengthened by a little intermediate fibrous tissue, and the bases of the cusps are generally continuous with each other at the auriculo-ventricular orifice, where they are attached to a fibrous ring, but they may be separated by small intermediate lobes which fill the angles between the main segments. The apices of the cusps hang down into the ventricle. The margins, which are thinner than the central portions, are notched and irregular. The auricular surfaces are smooth. The ventricular surfaces are roughened, and, like the margins and apices, they give attachment to fine tendinous cords, the **chordæ tendineæ,** the opposite extremities of which are attached to muscular bundles, the **musculi papillares,** which project from the wall into the cavity of the ventricle.

The **pulmonary orifice**, which lies in front and to the left of the tricuspid orifice, is guarded by a **pulmonary valve** composed of three semilunar segments (valvulæ semilunares a. pulmonalis), two of which are placed anteriorly and one posteriorly. The convexity or outer border of each semilunar segment is attached to the wall of the pulmonary artery. The inner border is free, and it presents at its centre a small nodule, the **corpus Arantii** (nodulus valvulæ semilunaris), and on each side of this body a small thin marginal segment of semilunar form, the **lunule** (lunula valvulæ semilunaris). Each segment of the valve is formed by a layer of endocardium on its ventricular surface, a layer of the inner coat of the artery on its arterial surface, and an intermediate stratum of fibrous tissue. Both the attached and the free margins of the cusps are strengthened by tendinous bands, and strands of condensed fibrous tissue radiate from the outer borders to the corpora Arantii, but they do not enter the lunulæ. When the valve closes the corpora Arantii are closely apposed, the lunulæ of the adjacent segments of the valve are pressed together, and they project vertically upwards into the interior of the artery.

The cavity of the right ventricle is lined by endocardium; the walls are smooth in the conus arteriosus, but are rendered rugose and sponge-like in the body by the inward projection of numerous muscular bundles, the **columnæ carneæ** (trabeculæ carneæ). These bundles are of three kinds; the simplest are merely columns raised in relief on the wall of the ventricle; those of the second class are rounded bundles, free in the middle, but attached at each end to the wall of the ventricle. One special bundle of this group, called the **moderator band,** is attached by one extremity to the septum, and by the other to the antero-superior wall, at the base of the anterior papillary muscle; it tends to prevent over-distension of the cavity. The third group of columnæ carneæ are the **musculi papillares,** conical bundles continuous at their bases with the muscular wall of the ventricle, and terminating at their apices in numerous chordæ tendineæ which are attached to the apices, the borders, and ventricular surfaces of the cusps of the tricuspid valve.

The musculi papillares of the right ventricle are—(1) a large anterior muscle, from which the chordæ pass to the infundibular and marginal segments of the valve; (2) a smaller and more irregular posterior muscle, sometimes represented by two or more segments, from which chordæ pass to the marginal and septal cusps; and (3) a group of muscular bundles, varying in size and number, which spring from the septum and are united by chordæ to the infundibular and septal cusps.

The walls of the right ventricle, the septal excepted, are much thinner than those of the left, but the columnæ carneæ of the first and second classes are coarser and less numerous in the right than in the left ventricle.

The **left ventricle** (ventriculus sinister) is a conical chamber, and its cavity is oval in transverse section. The base is directed upwards and backwards, and in the greater part of its extent it is continuous with the corresponding auricle with which it communicates through the mitral orifice, but in front and to the right of its communication with the auricle it is continued into the ascending aorta.

The **mitral orifice** is oval; its long axis runs obliquely from above and to the left downwards and to the right, and it is guarded by a valve consisting of two cusps, which is known as the **mitral valve** (valvula bicuspidalis). The two cusps of the valve are triangular and of unequal size. The smaller of the two, placed to the left and behind, is named the marginal, and the larger, placed to the right and in front, between the mitral and aortic orifices, is known as the **aortic**

cusp. The bases of the cusps are either continuous with each other at their attachments to the fibrous ring round the mitral orifice, or they are separated by small intermediate cusps of irregular form and size. The apices of the cusps hang down into the cavity of the ventricle. The auricular surfaces are smooth; the ventricular surfaces are roughened by the attachments of the chordæ tendineæ, which are also connected with the irregular and notched margins and with the apices. The structure is the same as that of the cusps of the tricuspid valve, but the ventricular surface of the anterior (or aortic) cusp is relatively smooth.

The **aortic orifice** is circular; it lies immediately in front and to the right of the mitral orifice, from which it is separated by the anterior cusp of the mitral valve, and it is guarded by the **aortic valve**, formed of three semilunar segments (valvulæ semilunares aortæ), one of which is placed anteriorly and the other two posteriorly. The structure of these cusps and their attachments are similar to those of the cusps of the pulmonary valve.

The cavity of the left ventricle is separable, like that of the right, into two portions, the body and the aortic vestibule; the latter is a small section placed immediately below the aortic orifice, and its walls are non-contractile, consisting of fibrous and fibro-cartilaginous tissue. The cavity is lined by endocardium. The inferior wall and the apex are rendered sponge-like by numerous fine columnæ carneæ of the first and second classes, whilst the upper part of the antero-superior wall and the septum are relatively smooth.

There are two papillary muscles of much larger size than those met with in the right ventricle—an anterior and a posterior; each is connected by chordæ tendineæ with both cusps of the mitral valve.

The walls of the left ventricle, with the exception of the septum, are three times as thick as those of the right ventricle, and they are thickest in the region of the widest portion of the cavity, which is situated about a fourth of its length from the base. The muscular portion of the wall attains its minimum thickness at the apex, but the thinnest portion of the boundary is at the upper part of the septum, which consists entirely of fibrous tissue; here it is occasionally deficient, and an aperture is left through which the cavities of the two ventricles communicate.

The **interventricular septum** (septum ventriculorum) is a musculo-membranous partition. It is placed obliquely, one surface looking forwards and to the right and bulging into the right ventricle, and the other backwards and to the left towards the left ventricle. Its antero-superior and inferior margins correspond respectively with the anterior and inferior portions of the interventricular sulcus, and it extends from the right of the apex to the interval between the pulmonary and aortic orifices. In the main part of its extent it is muscular (septum musculare ventriculorum), and this portion is developed from the wall of the ventricular part of the heart; but its upper and posterior portion, the **pars membranacea** (septum membranaceum ventriculorum), which is developed from the septum of the aortic bulb, is entirely fibrous, and constitutes the thinnest portion of the ventricular walls. The pars membranacea lies between the aortic vestibule on the left and the upper part of the right ventricle, as well as the lower and left part of the right auricle, on the right.

Structure of the Heart.

The walls of the heart consist mainly of peculiar striped muscle, the **myocardium**, which is enclosed between the visceral layer of the pericardium, or **epicardium**, externally, and the **endocardium** internally. The muscular fibres differ from those of ordinary voluntary striped muscle in several ways: they are shorter, many of them being oblong cells with forked extremities which are closely cemented to similar processes of adjacent cells; they form a reticulum, and the nuclei lie in the centres of the cells. Moreover, in some of the lower mammals, in the young child up to the end of the first year, and occasionally in the human adult also, still more peculiar fibres, the **fibres of Purkinje**, are found immediately beneath the sub-endocardial tissue. These are large cells which unite with each other at their extremities; their central portions consist of granular protoplasm, in which sometimes one, but more frequently two nuclei are embedded, and the peripheral portion of each cell is transversely striated. These cells, in short, present in a permanent form a condition which is transitory in all other striped muscle cells.

The reticulating cardiac muscle cells are grouped in sheets and strands which have a more or less characteristic and definite arrangement in different parts of the heart; by careful dis-

section, and after special methods of preparation, it is possible to recognise many layers and bundles, some of which are, however, probably artificially produced.

In the **auricles** the muscular fasciculi fall naturally into two groups, those special to each auricle, and those common to both auricles; the former are situated deeply under cover of the latter.

The *deep special fibres* are—(*a*) Looped fibres which pass over the auricles from before backwards or from side to side; their extremities are attached to the fibrous rings which surround the auriculo-ventricular orifices. (*b*) Annular fibres which surround (1) the extremities of the large vessels which open into the auricle, (2) the auricular appendices, and (3) the fossa ovalis.

The *superficial fibres*, which are common to both auricles, for the most part run transversely across the auricles, but a few of them turn into the interauricular septum. They are most numerous on the anterior aspect.

In the **ventricles**, also, two main groups of fasciculi, a superficial and a deep, have been described, but it is in this region especially that there is doubt regarding the individuality of many of the muscular bundles which have been noted, for it appears probable that many of them are artificial products due to the method adopted by the dissector. There is no doubt that in the middle of the thickness of the ventricular walls the arrangement of the fibres is mainly circular, some surrounding one and some both ventricles. Near the surfaces the fasciculi assume an oblique direction, and it is not improbable that many of the bundles are arranged in figure of 8 loops, whose upper extremities are attached to the fibrous rings round the auriculo-ventricular orifices.

The *superficial fibres* of the ventricles are attached above to the fibrous rings at the base, and from this attachment they pass obliquely downwards to the apex, those on the anterior surface trending towards the left, and those on the inferior surface towards the right. On the inferior surface almost all the fasciculi appear to pass across the septum, but on the anterior surface the middle fasciculi dip into it, and only those near the base and apex cross from right to left. All the superficial fibres which reach the apex are coiled there into a whorl or vortex, through which they pass upwards into the substance of the left ventricle, those descending from the front and left side entering the base of the posterior papillary muscle, whilst those from the back and right side terminate in the anterior papillary muscle. The muscular fasciculi which enter the papillary muscles are continued, by means of the chordæ tendineæ, to the flaps of the mitral valve and so to the fibrous ring round the mitral orifice; obviously, therefore, many of the superficial fasciculi of the ventricles form simple oblique loops which commence externally at the fibrous rings round the right and left auriculo-ventricular orifices, and terminate internally by gaining attachment to the ring round the left of these orifices (mitral).

The *deep fasciculi* of the ventricles may be subdivided into two main groups—(1) Those common to both ventricles, and (2) those special to each ventricle.

The fasciculi common to both ventricles include—(*a*) Fibres which commence above from the posterior sections of the fibrous ring at the base of the right ventricle; either directly or by means of the chordae tendineæ of the posterior papillary muscle they pass obliquely downwards to the septum, traverse it, and ascend to the front of the fibrous ring at the base of the left ventricle. (*b*) Fibres from the anterior portions of the fibrous ring at the base of the right ventricle, which pass obliquely downwards and assume a transverse course in the posterior wall of the left ventricle. (*c*) Annular fibres which encircle both ventricles.

The deep special fibres of the left ventricle are (*a*) V-shaped loops which commence at the fibrous ring at the base, and descend to the apex, where they turn upwards in the septum, and terminate by joining the central fibro-cartilage; (*b*) fibres which descend from the base, enter the lower and front part of the septum, and, passing through it, assume an annular course in the posterior wall.

The deep special fibres of the right ventricle are (*a*) looped fibres which pass downwards in the external wall from the fibrous rings to the apex, where they enter the septum and ascend to the central fibro-cartilage; (*b*) circular fibres round the pulmonary orifice; and (*c*) radiating fasciculi from the base of the anterior papillary muscle to the front part of the pulmonary orifice.

The **epicardium**, or visceral portion of the pericardium, consists of white connective and of elastic tissue, the latter forming a distinct reticulum in the deeper part. The surface which looks towards the pericardial cavity is covered with flat polygonal endothelial plates, which are partially separated here and there by stomata through which the pericardial cavity communicates with the lymphatics of the epicardium.

The **endocardium** lines the cardiac cavities and is continuous with the inner coats of the vessels which enter and leave the heart. It consists, like the epicardium, of white connective tissue and elastic fibres, but it is much thinner than the epicardium, and its elastic fibres are in some places blended into a fenestrated membrane. Its inner surface is covered with endothelial cells, and it rests externally upon the sub-endocardial tissue, in which there are blood-vessels and nerves; the endocardium itself is entirely devoid of vessels.

Size of the Heart.—The heart is about five inches (125 mm.) long, three and a-half inches (87 mm.) broad; its greatest depth from its antero-superior to its inferior surface is two and a-half inches (62 mm.), and it is roughly estimated as being about the same size as the closed fist. The size, however, is variable, the volume increasing at first rapidly, and then gradually, with increasing age, from 22 cc. at birth to 155 cc. at the fifteenth year, and to 250 cc. by the twentieth year. From this period to the fiftieth year, when the maximum volume (280 cc.) is attained, the increase is much more gradual, and after fifty a slight decrease sets in. The volume is the same in both sexes up to the period of puberty, but thereafter it preponderates in the male.

Weight.—The average weight of the heart in the male adult is 11 ounces (310 grms.), and in the female adult 9 ounces (255 grms.); but the weight varies greatly, always, however, in definite relation to the weight of the body, the relative proportions changing at different periods of life. Thus at birth the heart weighs 13½ drachms (24 grms.), and its relation to the body weight is as 1 to 130, whilst in the adult the relative proportion is as 1 to 205. The heart is said to rapidly increase in weight up to the seventh year, then more slowly up to the age of puberty, when a second acceleration sets in; but after the attainment of adult life the increase, which continues till the seventieth year, is very gradual.

The above changes affect the whole heart, but the several parts also vary in their relation to each other at different periods of life. During fœtal life the right auricle is heavier than the left; in the first month after birth the two become equal, and at the second year the right again begins to preponderate, and it is heavier than the left during the remainder of life. In the latter part of fœtal life the two ventricles are equal; after birth the left grows more rapidly than the right, until, at the end of the second year, a position of stability is gained, when the right is to the left as 1 to 2, and this proportion is maintained until death.

Capacity.—During life the capacity of the ventricles is probably the same, and each is capable of containing about four ounces of blood, whilst the auricles are a little less capacious. After death the cavity of the right ventricle appears larger than that of the left.

Vascular Supply of the Heart.—The walls of the heart are supplied by the **coronary arteries** (p. 755), the branches of which pass through the interstitial tissue to all parts of the muscular substance and to the sub-endocardial and sub-epicardial tissues; the endocardium and the valves are devoid of vessels. The capillaries, which are numerous, form a close-meshed network around the muscular fibres. Sometimes the valves contain a few muscular fibres, and in these cases they also receive some minute vessels. The majority of the veins of the heart end in the coronary sinus, which opens into the lower part of the right auricle; some few very small veins, however, open directly into the right auricle, and others are said to end in the left auricle, and in the cavities of the ventricles.

Lymphatics of the Heart.—Lymphatic vessels are freely distributed throughout the whole substance of the heart, but they are most numerous in the sub-endocardial and the sub-pericardial tissues, and the vessels which lie in the latter situation communicate through stomata with the pericardial cavity. The smaller lymphatic vessels accompany the blood-vessels; ultimately they converge to two main trunks—an anterior and an inferior—which lie respectively in the anterior and the inferior interventricular sulci. Having collected lymph from the ventricles, these vessels pass to the base of the heart, where they receive additional tributaries from the auricles; after passing by the roots of the great arteries, they terminate in the glands which lie round the bifurcation of the trachea.

Nerves of the Heart.—The heart receives its nerves from the superficial and deep cardiac plexuses which lie beneath the arch of the aorta, and through them it is connected with the vagus, the spinal accessory (through the vagus), and the sympathetic nerves. After leaving the plexuses many of the nerve fibres enter the walls of the auricles, and anastomose together in the sub-epicardial tissue, forming a plexus in which many ganglion cells are embedded, especially near the terminations of the inferior vena cava and the pulmonary veins. From the sub-epicardial auricular plexus, nerve filaments, on which nerve ganglion cells have been found, pass into the substance of the auricular walls.

Other fibres from the cardiac plexuses accompany the coronary arteries to the ventricles, and upon these also ganglion cells are found in the region immediately below the auriculo-ventricular sulcus.

The nerve fibres which issue from the ganglionated plexuses of the heart are non-medullated. They form fine plexuses round the muscle fibres, and they terminate either in fine fibrils on the surfaces of the muscle fibres, or in nodulated ends which lie in contact with the muscle cells.

THE PERICARDIUM.

The **pericardium** is a fibro-serous sac which surrounds the heart. It lies in the middle mediastinum, and is attached below to the diaphragm, and above and behind to the roots of the great vessels. Anteriorly and posteriorly it is to a great extent free; laterally it is in close apposition with the pleural sacs.

The **fibrous pericardium** is a strong fibrous sac of conical form; its base is attached to the central tendon and to a part of the muscular substance of the diaphragm, and it is pierced by the inferior vena cava. At its apex it is gradually lost upon the great vessels which enter and emerge from the heart, giving sheaths to the aorta, the two branches of the pulmonary artery, the superior vena cava, the four pulmonary veins, and the ligamentum arteriosum. Its anterior surface forms the posterior boundary of the anterior mediastinum, and it gives attachment, above and below, to the superior and inferior sterno-pericardial ligaments. In the greater part of its extent it is separated from the anterior wall of the thorax by the anterior margins of the lungs and pleural sacs, but it is in direct relation with the left half of the lower portion of the body of the sternum and, in many

cases, with the inner ends of the cartilages of the fourth, fifth, and sixth ribs of the left side. Its posterior surface forms the anterior boundary of the posterior mediastinum; it is in relation with the œsophagus and the descending aorta, both of which it separates from the back of the left auricle. Each lateral aspect is in close contact with the mediastinal portion of the parietal pleura, the phrenic nerve and its accompanying vessels intervening. The inner surface of the fibrous sac is lined by the serous pericardium, which is closely attached to it.

The **serous pericardium** is a closed sac containing a little fluid (liquor pericardii). It is surrounded by the fibrous pericardium and invaginated by the heart. It is, therefore, separable into two portions—the parietal, which lines the inner surface of the fibrous sac, and the visceral, which ensheaths, or partially ensheaths, the

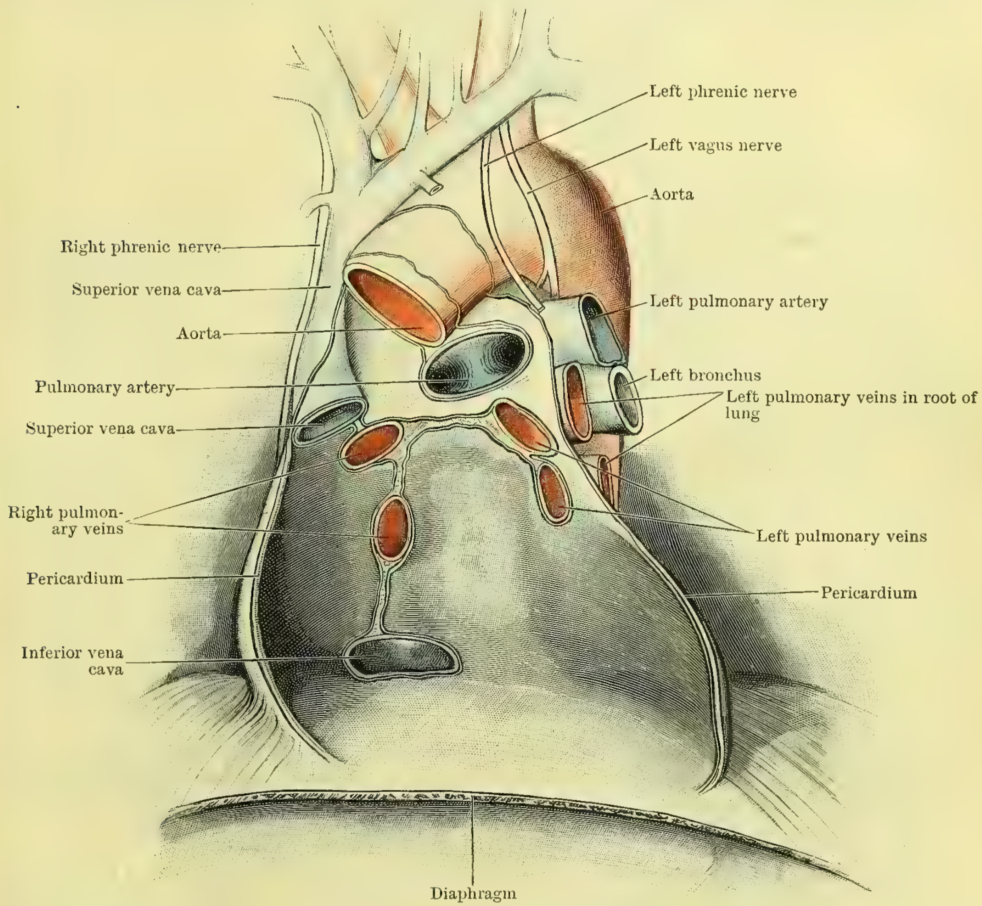


Fig. 551.—Posterior Wall of the Pericardium after removal of the Heart, showing the relation of the serous pericardium to the great vessels. From a formalin preparation made by Professor Birmingham.

heart and the great vessels; but the two portions are, of course, continuous with each other where the serous layer is reflected on to the great vessels as they pierce the fibrous layer. The majority of the great vessels receive only partial coverings from the visceral layer: thus the superior vena cava is covered in front and laterally; the pulmonary veins in front, above, and below; and the inferior vena cava, for a very short distance, in front and laterally. The aorta and the pulmonary artery are enclosed together in a complete sheath of the visceral layer; and when the pericardial sac is opened from the front it is possible to pass the fingers behind them and in front of the auricles, from the right to the left side, through a passage called the **great transverse sinus** of the pericardium. The spaces or pouches which intervene between the vessels which receive partial coverings from the serous pericardium are also called sinuses; and the largest of them, which

is bounded below and on the right by the inferior vena cava and above and on the left by the left inferior pulmonary vein, is known as the **great oblique sinus.** It passes upwards and to the right behind the auricles, and lies in front of the œsophagus and the descending thoracic aorta.

A small fold of the serous pericardium, the **vestigial fold** of Marshall (ligamentum v. cavæ sinistræ), passes from the left pulmonary artery to the left superior pulmonary vein behind the left extremity of the transverse sinus. It merits special attention because it encloses the remains of the left superior vena cava, which atrophies at an early period of fœtal life.

Structure.—The fibrous pericardium consists of ordinary connective tissue fibres felted together into a dense unyielding membrane. The serous pericardium is covered on its inner aspect by a layer of flat endothelial cells which rest upon a basis of mixed white and elastic fibres in which run numerous blood-vessels, lymphatics, and nerves.

THE ARTERIES.

THE PULMONARY ARTERY.

The **pulmonary artery** (a. pulmonalis), which is slightly larger at its commencement than the aorta, springs from the anterior and left angle of the base of the right ventricle, at the termination of the infundibulum. It runs upwards and backwards towards the concavity of the aortic arch, curving from the front round the left side of the ascending aorta to reach a plane posterior to the latter; and it terminates, by dividing into right and left branches, opposite the disc between the fifth and sixth dorsal vertebræ. Its length is a little more than two inches.

Relations.—Enclosed within the fibrous pericardium, and enveloped along with the ascending aorta in a common sheath of the visceral layer of the serous pericardium, the pulmonary artery lies behind the inner extremity of the second left intercostal space, from which it is separated by the anterior margins of the left lung and pleural sac.

Its posterior relations are the root of the aorta, the anterior wall of the left auricle, and the first part of the left coronary artery. To the right it is in relation with the right coronary artery and the right auricular appendix, and to the left with the left coronary artery and the left auricular appendix. Immediately above its bifurcation, between it and the aortic arch, is the superficial cardiac plexus.

The **right branch of the pulmonary artery** is longer and larger than the left. It passes to the hilus of the right lung, forming one of the constituents of its root, and, entering the lung, descends with the main bronchus to the lower extremity of the organ.

Relations.—Before it enters the lung the right pulmonary artery passes behind the ascending aorta, the superior vena cava, and the upper right pulmonary vein. At first it lies below the arch of the aorta and the right bronchus, in front of the œsophagus, and above the left auricle and the lower right pulmonary vein; then it crosses in front of the right bronchus immediately below the eparterial branch, and reaches the hilus of the lung. After entering the lung the artery descends, behind and to the outer side of the main bronchus and between its ventral and dorsal branches.

Branches.—Before entering the hilus it gives off a large branch to the upper lobe which accompanies the eparterial bronchus, and in the substance of the lung it gives off numerous branches which correspond with and accompany the dorsal, ventral, and accessory branches of the right bronchus.

The **left branch of the pulmonary artery**, shorter, smaller, and somewhat higher in position than the right, passes outwards and backwards from the bifurcation of the pulmonary stem, and runs in the root of the left lung to the hilus; it then descends in company with the main bronchus to the lower end of the lung.

Relations.—Before it enters the lung it is crossed in front by the upper left

pulmonary vein; *behind* it, is the left bronchus; *above*, the aortic arch, to which it is connected by the ligamentum arteriosum, and the left recurrent laryngeal nerve; *below*, it is in relation with the lower left pulmonary vein. After entering the lung it descends, like the right pulmonary artery, behind and on the outer side of the stem bronchus, and between its ventral and dorsal branches.

Branches.—Just before passing through the hilus it gives off a branch to the

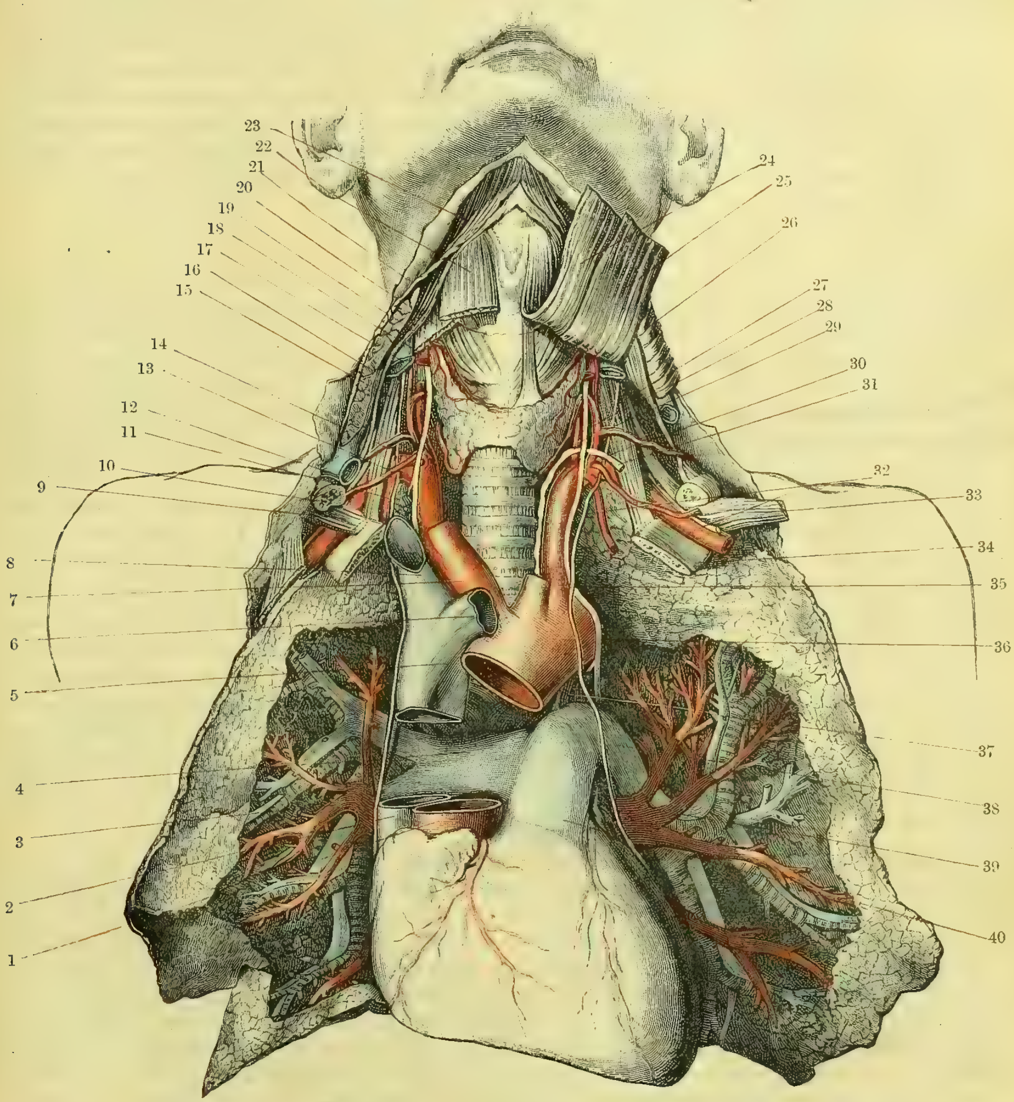


Fig. 552.—The Pulmonary Arteries and Veins and their Relations.
Parts of the ascending aorta and superior vena cava have been removed.

1. Aorta.
2. Superior vena cava.
3. Upper right pulmonary vein.
4. Right pulmonary artery.
5. Superior vena cava.
6. Left innominate vein.
7. Innominate artery.
8. Right innominate vein.
9. Subclavius muscle.
10. Clavicle.
11. Internal mammary artery.
12. Subclavian vein.
13. Suprascapular artery.
14. Transverse cervical artery.
15. Vertebral artery.
16. Inferior thyroid artery.
17. Internal jugular vein.
18. Common carotid artery.
19. Superior thyroid artery.
20. Sterno-thyroid muscle.
21. Omo-hyoid muscle.
22. Sterno-hyoid muscle.
23. Platysma.
24. Sterno-hyoid muscle.
25. Sterno-thyroid muscle.
26. Sterno-mastoid muscle.
27. Phrenic nerve.
28. Vagus nerve.
29. Vertebral artery.
30. Inferior thyroid artery.
31. Thoracic duct.
32. Left subclavian artery.
33. Subclavius muscle.
34. 1st rib.
35. Left common carotid artery.
36. Aorta.
37. Ligamentum arteriosum.
38. Left pulmonary artery.
39. Upper left pulmonary vein.
40. Pulmonary artery.

upper lobe, and in the substance of the lung its branches correspond with the ventral, dorsal, and accessory branches of the bronchial tube.

THE SYSTEMIC ARTERIES.

THE AORTA.

The **aorta** is the main trunk of the arterial system. It commences at the base of the left ventricle and ascends, with an inclination to the right, to the level of the second right costal cartilage; then curving backwards and to the left, it reaches the left side of the lower border of the fourth dorsal vertebra, and finally descends through the thorax into the abdomen, where it terminates on the left side of the fourth lumbar vertebra by bifurcating into the two common iliac arteries. The portion of the aorta which is situated in the thorax is for convenience termed the thoracic aorta, and the rest of the vessel is known as the abdominal aorta.

THE THORACIC AORTA.

The thoracic aorta is subdivided into the ascending portion, the arch, and the descending portion.

The **ascending aorta** (aorta ascendens) lies in the middle mediastinum. It springs from the base of the left ventricle, behind the left margin of the sternum, opposite the lower border of the third left costal cartilage and the body of the fifth dorsal vertebra. From its origin it passes upwards, forwards, and to the right, and it terminates in the arch of the aorta, behind the right margin of the sternum, at the level of the second costal cartilage. Its *length* is from to 2 to $2\frac{1}{4}$ inches (50 to 57 mm.), and its breadth is $1\frac{1}{8}$ inches (28 mm.). In the adult it is a little narrower at its commencement than the pulmonary artery is, but in old age it enlarges and exceeds the latter vessel in size. The diameter, however, is not uniform throughout the whole length of the ascending aorta; four distinct dilatations are present. Three of these, small and pouch-like, are known as the sinuses of Valsalva (sinus aortæ). They are situated at the origin of the aorta, immediately above the semilunar cusps of the valve which guards the aperture of communication with the left ventricle; therefore one is anterior in position, and two are situated posteriorly. The fourth dilatation is formed by a diffuse bulging of the right wall, and is known as the *great sinus* of the aorta.

Relations.—The ascending aorta is completely enclosed within the fibrous pericardium, which blends above with the sheath of the vessel. It is enveloped, together with the stem of the pulmonary artery, in a tubular prolongation of the serous pericardium, and has the pulmonary artery in front, the anterior wall of the right auricle behind, and the right auricular appendix on its right side. In the upper part of its course the ascending aorta is overlapped by the anterior margins of the right lung and right pleural sac, whilst behind it are the right branch of the pulmonary artery, the upper right pulmonary vein, the right bronchus, and the left margin of the superior vena cava. The superior vena cava lies on the right side, and partly behind the upper part of the ascending aorta, whilst the pulmonary artery is at first in front of it and then, at a higher level, on its left side.

Branches.—Two branches arise from the ascending aorta, viz. the right and the left coronary arteries. The former springs from the anterior, and the latter from the left posterior sinus of Valsalva (p. 755).

The **arch of the aorta** (arcus aortæ) lies in the superior mediastinum behind the lower part of the manubrium sterni, and connects the ascending with the descending aorta. It commences behind the right margin of the sternum, on a level with the second costal cartilage, and extends to the lower border of the fourth dorsal vertebra. As its name implies, it forms an arch; in this there are two curvatures, one with the convexity upwards, and the other with the convexity forwards and to the left. From its origin it runs for a short distance upwards, backwards, and to the left, in front of the trachea; then it passes backwards round the left side of the trachea to the left side of the body of the fourth dorsal

vertebra, and finally turns downwards to become continuous with the descending aorta.

At its commencement it has the same diameter as the ascending aorta, $1\frac{1}{8}$ inches (28 mm.), but after giving off three large branches, the diameter is reduced to a little less than one inch (23 mm.).

Relations.—It is overlapped in front and on the left side by the right and left lungs and pleural sacs, but much more by the latter than the former, and in the interval between and behind the pleural sacs it is covered by the remains of the thymus gland. As it turns backwards it is crossed vertically on the left side by four nerves in the following order from before backwards—the left phrenic, the inferior cervical cardiac branch of the left vagus, the superior cardiac branch of the left sympathetic and the trunk of the left vagus, and the left superior intercostal vein passes obliquely upwards and to the right between the vagus and phrenic nerves.

Behind and *to the right side* of the arch are the trachea, the left recurrent laryngeal nerve, the left border of the œsophagus, and the thoracic duct. *Above* are its three large branches—the innominate, the left common carotid, and the left subclavian arteries—and crossing in front of the roots of these is the left innominate vein. *Below* is the bifurcation of the pulmonary artery and the root of the left lung ; the ligamentum arteriosum, which is also below, attaches it to the commencement of the left pulmonary artery, whilst to the right of the ligament is the superficial cardiac plexus, and to its left is the left recurrent laryngeal nerve.

Branches.—The three great vessels which supply the head and neck, part of the thoracic wall, and the upper extremities—viz. the innominate, the left common carotid, and the left subclavian arteries—arise from the aortic arch.

The **descending aorta** (aorta descendens).—The thoracic portion of the descending aorta lies in the posterior mediastinum; it extends from the termination of the arch, at the lower border of the left side of the fourth dorsal vertebra, to the aortic opening in the diaphragm, where, opposite the twelfth dorsal vertebra, it becomes continuous with the abdominal portion. Its length is from seven to eight inches (17·5 to 20 cm.), and its diameter diminishes from 23 mm. at its commencement to 21 mm. at its termination.

Relations.—Immediately *behind* it is the vertebral column and the anterior common ligament. It rests also on the vena azygos minor superior and the vena azygos minor inferior, whilst from its posterior aspect the aortic intercostal branches are given off.

In front it is in relation, from above downwards, with the root of the left lung, the pericardium which separates it from the back of the left auricle, the œsophagus with the œsophageal plexus of nerves, and the crura of the diaphragm which separate it from the Spigelian lobe of the liver. On the *left side* are the left lung and pleura. On the *right side* the thoracic duct and the vena azygos major form immediate relations along its whole length. The œsophagus also lies to the right of the upper part of the descending aorta, whilst the right lung and pleura are in close relation below.

Branches.—Nine pairs of aortic intercostal arteries, two left bronchial arteries, four or five œsophageal, some small pericardial, and a few posterior mediastinal branches usually arise from the descending aorta.

THE ABDOMINAL AORTA.

The abdominal portion of the descending aorta lies in the epigastric and umbilical regions of the abdomen. It extends from the middle of the lower border of the last dorsal vertebra to the left side of the body of the fourth lumbar vertebra, where it bifurcates into the right and left common iliac arteries. The point of division is a little below and to the left of the umbilicus, opposite a line drawn transversely across the abdomen on a level with the highest points of the iliac crests.

At its commencement it is 21 mm. in diameter, but after the origin of two large branches, the cœliac axis and the superior mesenteric arteries, it diminishes considerably, and then retains a fairly uniform diameter to its termination.

Relations.—*Behind*, it is in contact with the upper four lumbar vertebræ and

intervening intervertebral discs, the anterior common ligament, and the left lumbar veins; the lumbar and the middle sacral arteries spring from this aspect of the vessel. In *front*, and in close relation with it, there are from above downwards the following structures: the cœliac axis and solar plexus, the pancreas and splenic vein, the superior mesenteric artery, the left renal vein, the third part of the duodenum, the root of the mesentery, the aortic plexus, the inferior mesenteric artery, the peritoneum and coils of small intestine. More superficially the stomach, the transverse colon, and the great omentum are in front. On the *right side*, in the upper part of its extent, are the thoracic duct and receptaculum

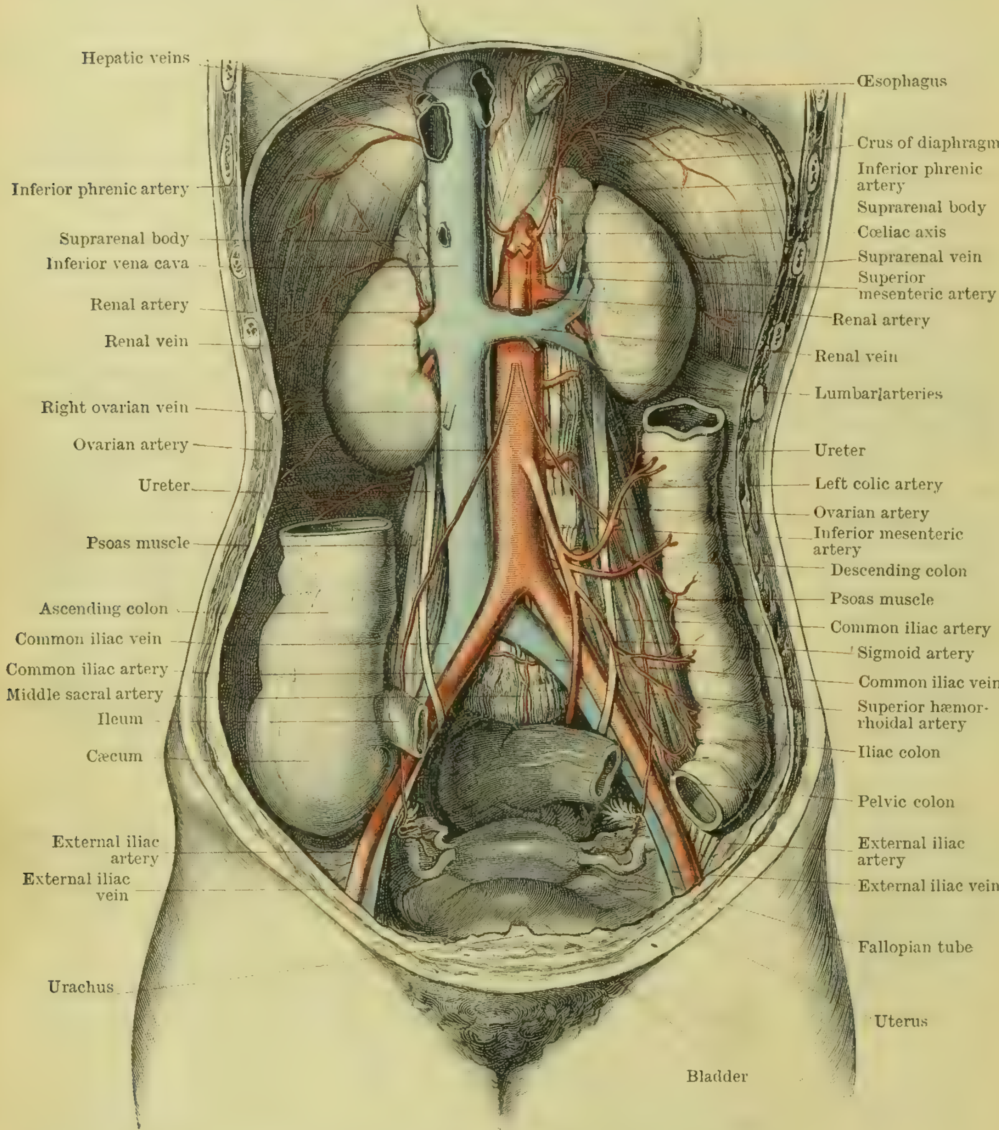


FIG. 553.—THE ABDOMINAL AORTA AND ITS BRANCHES.

chyli, the vena azygos major, and the right crus of the diaphragm, the latter separating it from the right semilunar ganglion and from the upper part of the inferior vena cava. In its lower part it is in direct relation with the inferior vena cava. On the *left side*, the left crus of the diaphragm with the left semilunar ganglion, and the fourth part of the duodenum, are in close relation with its upper part, whilst in the lower portion of its extent the peritoneum and some coils of the small intestine are in contact with it.

Branches.—The branches form two groups, visceral and parietal, and each group consists of paired and unpaired vessels, as follows:—

Visceral.		Parietal.	
Unpaired.	**Paired.**	**Unpaired.**	**Paired.**
Cœliac axis Superior mesenteric Inferior mesenteric	Suprarenal Renal Spermatic or ovarian	Middle sacral	Inferior phrenic Lumbar (four pairs) Common iliac

BRANCHES OF THE ASCENDING AORTA.

Coronary Arteries.

The coronary arteries are two in number, a right and a left; they are distributed almost entirely to the heart, but give also some small branches to the roots of the great vessels, and to the pericardium (Figs. 545, 546, and 549).

The **right coronary artery** (a. coronaria dextra) springs from the anterior sinus of Valsalva. It runs forwards, between the root of the pulmonary artery and the right auricular appendix, to the auriculo-ventricular sulcus, in which it passes to the right, and then, turning round the margin of the heart, is continued to the left as far as the posterior end of the inferior interventricular sulcus, where it ends by dividing into two terminal branches. It is accompanied by branches from the cardiac plexus, and is in relation with the right coronary vein.

Branches.—Of the two terminal branches, one, the **transverse** (ramus circumflexus), is of small size; it is simply the continuation of the main trunk which runs farther to the left to anastomose with the transverse branch of the left coronary artery. The other, the **interventricular** (ramus descendens), is much larger than the transverse branch. It runs forwards in the inferior interventricular sulcus, supplies both ventricles, and anastomoses, at the apex of the heart, with the interventricular branch of the left coronary artery.

In addition to the terminal branches small **aortic** and **pulmonary twigs** are distributed to the roots of the aorta and pulmonary artery respectively. A **right auricular branch** passes upwards on the anterior surface of the right auricle, between it and the ascending aorta; one or more preventricular branches, of small size, descend on the anterior surface of the right ventricle; a branch of larger size, the **marginal artery**, descends along the right margin and gives branches to both surfaces of the right ventricle.

The **left coronary artery** (a. coronaria sinistra) arises from the left posterior sinus of Valsalva. In its course and distribution it resembles in many respects the right coronary artery, the chief difference being that it divides much sooner into its two terminal branches; the trunk of the artery is therefore correspondingly short. From its origin it runs forwards between the root of the pulmonary artery and the left auricular appendix, and, reaching the auriculo-ventricular sulcus at the upper end of the anterior interventricular groove, divides immediately into transverse and interventricular terminal branches.

Branches.—The **transverse terminal branch** (ramus circumflexus) runs to the left margin of the heart, and there turns to the inferior surface where it comes into relation with the coronary sinus; it ends by anastomosing with the transverse branch of the right coronary artery. It supplies the left auricle, the left margin of the heart, and the posterior part of the lower surface of the left ventricle. The **interventricular terminal branch** (ramus descendens anterior) passes down the anterior interventricular sulcus to the apex of the heart, where it anastomoses with the interventricular branch from the right coronary; it supplies both ventricles, and is accompanied by cardiac nerves and by the great cardiac vein.

A **left auricular branch**, or branches of small size, pass to the wall of the left auricle, and small **aortic** and **pulmonary branches** are also given to the roots of the aorta and pulmonary artery.

BRANCHES OF THE ARCH OF THE AORTA.

The branches which arise from the arch of the aorta supply the head and neck, the upper extremities, and part of the body wall.

They are three in number, viz. the **innominate**, the **left common carotid**, and

the **left subclavian arteries**. The innominate is a short trunk from the termination of which the right common carotid and the right subclavian arteries spring (Figs. 552 and 556); thus there is at first a difference between the stem vessels of opposite sides, but beyond this the subsequent course and the ultimate distribution of these vessels closely correspond.

THE INNOMINATE ARTERY.

The **innominate artery** (a. anonyma, Fig. 552) arises behind the middle of the lower part of the manubrium sterni, from the convexity of the arch of the aorta near its right or anterior extremity, and terminates opposite the right sterno-clavicular articulation, where it divides into the right subclavian and right common carotid arteries.

Course.—The trunk, which measures from one and a half to two inches (37 to 50 mm.) in length, runs upwards, backwards, and outwards in the superior mediastinum.

Relations.—*Posterior.*—It is in contact behind, with the trachea below and with the right pleural sac above.

Anterior.—The left innominate vein crosses in front of the lower part of the artery, and above this the sterno-thyroid muscle separates it from the sterno-hyoid and the right sterno-clavicular joint. The anterior margin of the right pleural sac overlaps the artery, and the remains of the thymus gland, which separate it from the manubrium sterni, are also in front.

Lateral.—The right innominate vein and the upper part of the superior vena cava are on the right side of the artery. On its left side is the origin of the left common carotid artery, whilst at a higher level the trachea is in contact with it.

Branches.—As a rule the innominate artery does not give off any branches except its two terminals, but occasionally it furnishes an additional branch, the thyroidea ima.

The **thyroidea ima** is an inconstant and slender vessel. When present it sometimes arises from the arch of the aorta, but it usually springs from the lower part of the innominate. It passes upwards in front of the trachea, through the anterior part of the superior mediastinum and the lower part of the neck, and gives off branches to the lateral lobes and isthmus of the thyroid body and to the trachea.

THE ARTERIES OF THE HEAD AND NECK.

The vessels distributed to the head and neck are chiefly derived from the carotid trunks; there are, however, in addition, other vessels which arise from the main arterial stems of the upper extremities, and it will be advantageous to describe the most important of these, viz. the vertebral arteries, with the carotid system. The smaller additional branches will be considered along with the remaining branches of the subclavian arteries.

The **carotid system of arteries** consists on each side of a **common carotid trunk,** which divides into **internal** and **external carotid arteries**, from which numerous branches are given off.

The internal carotid arteries are distributed almost entirely to the contents of the cranial cavity internal to the dura mater, and to the structures in the cavity of the orbit. The external carotid arteries, on the other hand, supply structures of the head and neck more externally situated.

It is to be observed, however, that the vascular supply of the brain is not wholly derived from the internal carotid vessels, but that the vertebral arteries also contribute largely to it.

THE COMMON CAROTID ARTERIES.

The right and the left common carotid arteries are of unequal length. The right common carotid commences at the bifurcation of the innominate artery, behind the right sterno-clavicular articulation; the left arises in the superior mediastinum from the arch of the aorta, but each terminates at the level of the upper border of the thyroid cartilage; the left artery has thus a short intra-

thoracic course, and so far its relations call for separate consideration; whilst in the rest of its course it passes, like the right common carotid, upwards in the neck and has similar relations.

Thoracic Portion of the Left Common Carotid.—The thoracic or mediastinal portion of the left common carotid artery (a. carotis communis sinistra) extends from the upper aspect of the aortic arch, a little behind and to the left of the origin of the innominate artery, to the left sterno-clavicular articulation, where the cervical portion commences. It is about one or one and a half inches in length (25 to 37 mm.), and it runs upwards and slightly outwards through the upper part of the superior mediastinum, lying farther back than the innominate artery and, therefore, being more overlapped by pleura.

Relations.—*Posterior.*—The vessel is in contact behind and from below upwards with the trachea, the left recurrent laryngeal nerve, the œsophagus, and the thoracic duct.

Anterior.—The left innominate vein runs obliquely across the front of the artery, upon which cardiac branches from the left vagus and sympathetic descend vertically. These structures, together with the remains of the thymus gland and the anterior margins of the left lung and pleura, separate the artery from the manubrium sterni, and from the origins of the sterno-hyoid and sterno-thyroid muscles.

Lateral.—The innominate artery below and the trachea above are on the right side. The left pleura, and, on a posterior plane, the left phrenic and vagus nerves and the left subclavian artery are on its left side.

Cervical Portion of the Left Common Carotid Artery.—The cervical part of the left common carotid artery is about three and a half inches long; it extends from the left sterno-clavicular articulation to the level of the upper border of the thyroid cartilage and the lower border of the third cervical vertebra, where it ends by dividing into the external and internal carotid arteries.

Course.—It runs upwards, outwards, and backwards, through the muscular and the lower part of the carotid divisions of the anterior triangle of the neck. In the lower part of its extent it is separated from its fellow of the opposite side by the trachea and the œsophagus, and in the upper part by the relatively wide pharynx.

Relations.—It is enclosed, together with the internal jugular vein and the vagus nerve, in a sheath of deep cervical fascia—the **carotid sheath.**

Posterior.—The longus colli and scalenus anticus below and the rectus capitis anticus major above are separated from the posterior surface of the artery and sheath by the prevertebral fascia and the sympathetic cord. The inferior thyroid artery crosses close behind the vessel about the level of the first ring of the trachea; lower down the vertebral artery and the thoracic duct are posterior to it, and the vagus nerve lies behind and to its outer side.

Anterior.—The descendens cervicis nerve descends superficial to the artery, usually outside the sheath, but sometimes enclosed in it. Opposite the sixth cervical vertebra the omo-hyoid muscle and the sterno-mastoid branch of the superior thyroid artery cross the carotid artery, which is overlapped, above the omo-hyoid muscle, by the anterior border of the sterno-mastoid, and is frequently crossed by the superior thyroid vein. Below the omo-hyoid the artery is covered by the sterno-thyroid, the sterno-hyoid, and the sterno-mastoid muscles, and it may be overlapped by the lateral lobe of the thyroid body; it is also crossed beneath the muscles by the middle thyroid vein, whilst occasionally a communication between the common facial and anterior jugular veins descends in front of the artery along the anterior border of the sterno-mastoid. Just above the sternum the anterior jugular vein is in front of the artery, but separated from it by the sterno-hyoid and sterno-thyroid muscles.

Lateral.—The trachea and œsophagus, with the recurrent laryngeal nerve in the angle between them, are internal to the lower part of the artery; the pharynx and larynx are internal to its upper part. The carotid gland lies immediately to the inner side of the termination of the artery.

The internal jugular vein occupies the outer part of the carotid sheath, and lies to the outer side of the artery, which it also overlaps in front, especially in the lower part of its extent.

Branches.—As a rule no branches are given off from either of the common carotid arteries except the terminal branches and some minute twigs from each to the corresponding carotid sheath and carotid body.

The **right common carotid artery**, as already stated, differs as regards origin from the left common carotid. In length and general position it corresponds with the cervical portion of the left common carotid, and its relations also are very similar. Such differences as exist may be briefly summarised as follows:—The internal jugular vein on both sides lies external to the artery; on the left side it runs well in front of the carotid artery in the lower part of the neck, whilst on the right side the vein is separated from the outer surface of the artery at its lower end by a well-marked interval in which the vagus nerve appears. The thoracic duct does not come into relation with the right common carotid, and there is also a

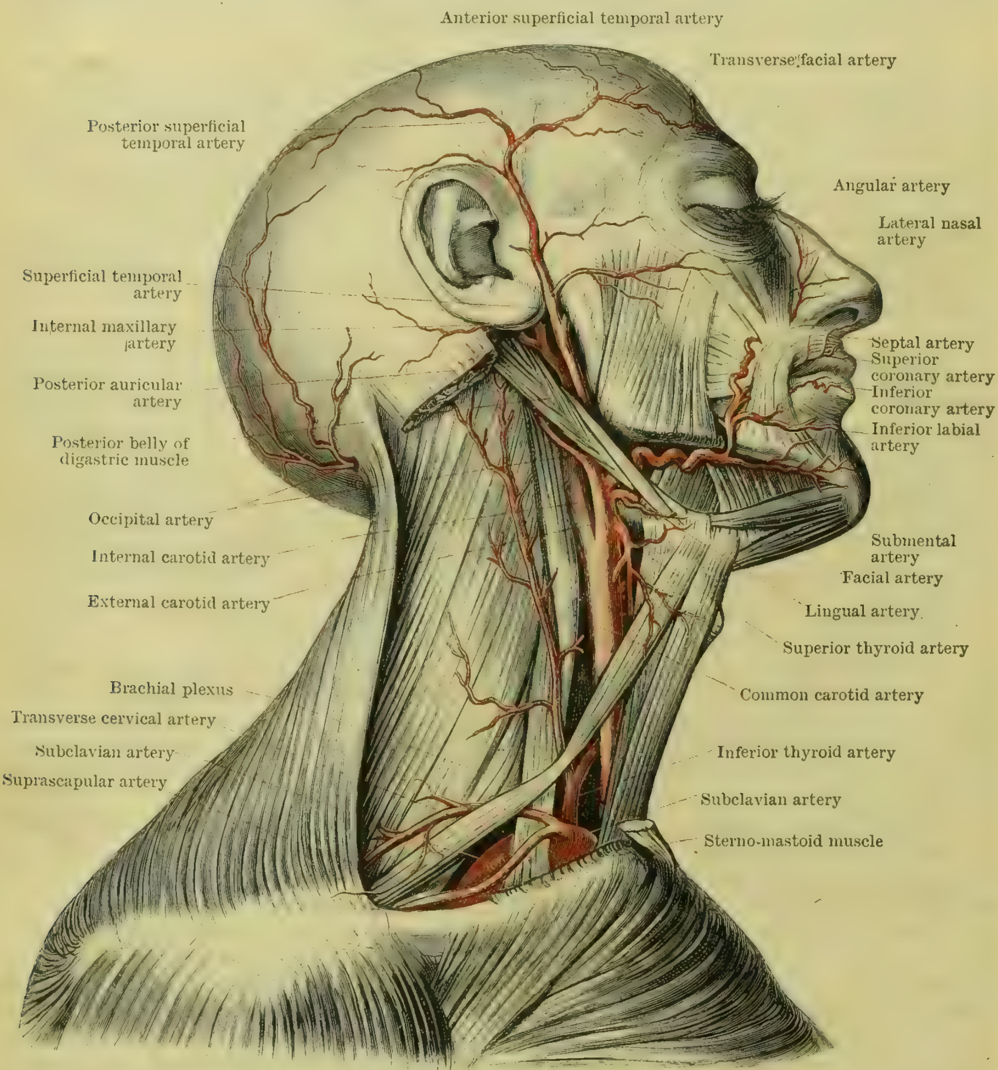


FIG. 554.—THE CAROTID AND SUBCLAVIAN ARTERIES AND THEIR BRANCHES.

difference in the relations of the recurrent laryngeal nerves to the arteries on the two sides. On the left side the nerve crosses behind the mediastinal part of the left artery, and lies internal to its cervical part, whilst the corresponding nerve on the right side passes behind the lower part of the carotid artery in the neck to reach its inner side.

THE EXTERNAL CAROTID ARTERY.

The external carotid artery (a. carotis externa, Fig. 555) is the smaller of the two terminal branches of the common carotid; its length is about two and a half inches

(62 mm.). It extends from the upper border of the thyroid cartilage to the back of the neck of the mandible, where it terminates by dividing into the superficial temporal and the internal maxillary arteries.

Course.—It commences in the carotid triangle, passes upwards beneath the posterior belly of the digastric and the stylo-hyoid muscles to enter the posterior part of the submaxillary triangle, where it disappears beneath the lower part of the parotid gland, and it terminates under cover, or in the substance of the upper part of the gland.

At its commencement it lies somewhat in front of and to the inner side of the internal carotid artery, but, inclining slightly backwards as it ascends, it becomes superficial to the latter vessel, and its course is indicated by a line drawn from the lobule of the ear to the posterior extremity of the great cornu of the hyoid bone.

Relations.—*Posterior.*—In the lower part of its extent it is in close relation with the internal carotid, and in the upper part of its course with the cartilaginous portion of the external auditory meatus.

Lateral.—At its commencement the fibres of the inferior constrictor muscle are in contact with its inner side, but at a higher level the structures which intervene between it and the internal carotid—viz. the stylo-pharyngeus muscle, the tip of the styloid process, the stylo-glossus muscle, the glosso-pharyngeal nerve, and the pharyngeal branch of the vagus—separate it from the wall of the pharynx; whilst internal both to it and to the internal carotid artery are the external and internal laryngeal branches of the superior laryngeal nerve.

Superficial.—In the carotid triangle the lingual, ranine, common facial, and superior thyroid veins are superficial to it, and the hypoglossal nerve crosses the artery immediately below the origin of its occipital branch. On the boundary line between the carotid and the submaxillary triangles the posterior belly of the digastric and the stylo-hyoid muscles cover the artery, and from the tip of the mastoid process downwards it is overlapped by the anterior border of the sterno-mastoid muscle. Above the posterior belly of the digastric the parotid gland is superficial to the artery, while still more superficially are the superficial fascia and the skin. In the substance of the parotid gland the temporo-maxillary vein descends on the outer side of the artery, and the facial nerve crosses on the outer side of the vein at a right angle to it.

Branches.—Eight branches arise from the external carotid artery; of these three spring from its anterior aspect, viz. the superior thyroid, the lingual, and the facial, all of which arise in the carotid triangle; two from its posterior aspect, viz. the occipital and the posterior auricular, the former commencing below the posterior belly of the digastric and the latter above it; one from its inner side, viz. the ascending pharyngeal, which rises in the carotid triangle; and two from its termination, viz. the superficial temporal and the internal maxillary.

Branches of the External Carotid Artery.

(1) **Superior Thyroid Artery** (a. thyroidea superior, Figs. 554 and 556).—This vessel springs from the front of the lower part of the external carotid artery, just below the tip of the great cornu of the hyoid bone, and terminates at the upper extremity of the lateral lobe of the thyroid body by dividing into its terminal branches.

Course.—From its commencement in the carotid triangle the artery runs at first forwards and a little upwards, it then turns downwards to its termination.

Relations.—*Internally* it is in relation with the inferior constrictor muscle and the external laryngeal branch of the superior laryngeal nerve.

Superficially it is covered at its origin by the anterior border of the sterno-mastoid; afterwards, for a short distance, by fascia, platysma, and skin, and in the lower part of its extent by the omo-hyoid, the sterno-hyoid, and the sterno-thyroid muscles, and it is overlapped by an accompanying vein.

Branches.—(1) *In the carotid triangle* (*a*) an **infra-hyoid branch** (ramus hyoideus) runs along the lower border of the great cornu of the hyoid bone, under cover of the thyro-hyoid muscle, to anastomose with its fellow of the opposite side and with the supra-hyoid branch of the lingual artery. It supplies the thyro-hyoid muscle and membrane.

(*b*) A **laryngeal branch** (a. laryngea superior) runs forwards beneath the thyro-hyoid muscle. It pierces the thyro-hyoid membrane in company with the internal laryngeal nerve, supplies the muscles, ligaments, and mucous membrane of the larynx, and

anastomoses with its fellow of the opposite side, with branches of the crico-thyroid artery and with the terminal branches of the inferior thyroid artery.

(*c*) The **sterno-mastoid branch** (ramus sterno-cleidomastoideus) passes downwards and backwards along the upper border of the anterior belly of the omo-hyoid muscle and across the common carotid artery to the under surface of the sterno-mastoid muscle. It anastomoses, in the sterno-mastoid, with branches of the occipital and suprascapular arteries.

(2) *In the muscular triangle* (*d*) a **crico-thyroid branch** (ramus crico-thyroideus) runs forwards, either over or under the sterno-thyroid, and crosses the crico-thyroid muscle to anastomose in front of the crico-thyroid membrane with its fellow of the opposite side, and, by branches which perforate the crico-thyroid membrane, with laryngeal branches of the superior and inferior thyroid arteries. It supplies the adjacent muscles and membrane.

(*e*) The **terminal branches** are **anterior** and **posterior** respectively.

The **anterior terminal branch** (ramus anterior), often much larger than the crico-thyroid artery, descends along the anterior border of the lateral lobe of the thyroid body, and, extending on to the upper border of the thyroid isthmus, anastomoses with its fellow of the opposite side. The **posterior branch** (ramus posterior) descends along the posterior border of the lateral lobe, and both terminal branches supply the thyroid body (rami glandulares). They anastomose with each other and with branches from the inferior thyroid artery.

(2) **Lingual Artery.**—The lingual artery (a. lingualis, Figs. 554 and 556) springs from the front of the external carotid, opposite the tip of the great cornu of the hyoid bone, and terminates, as the ranine artery, beneath the tip of the tongue, where it anastomoses with its fellow of the opposite side.

Course.—From its commencement, and whilst in the carotid triangle, the first part of the artery forms a loop with the convexity upwards. A second part passes forwards, immediately above the great cornu of the hyoid bone, to the anterior border of the hyo-glossus muscle, where it gives off a sublingual branch. A third part passes obliquely forwards and upwards under cover of the anterior border of the hyo-glossus, and a fourth part runs directly forwards on the under surface of the tongue to the tip. The third and fourth parts are frequently described together as the **ranine artery** (a. profunda linguæ).

Relations.—The first part of the lingual artery is crossed superficially by the hypoglossal nerve, but beyond this it is only covered by skin, fascia, and the platysma; it rests internally against the middle constrictor of the pharynx. In the rest of its course the artery is for the most part more deeply placed. The second part, remaining in contact internally with the middle constrictor, passes beneath the hyo-glossus muscle, by which it is separated from the hypoglossal nerve, the ranine vein, and the lower part of the submaxillary gland. The third part ascends almost vertically, parallel with and under the anterior fibres of the hyo-glossus, which is here covered by the mylo-hyoid, and between it and the genio-hyo-glossus. The fourth part runs forwards between the inferior lingualis and the genio-hyo-glossus muscles, and is only covered on its lower surface by the mucous membrane of the tongue. Thus the lingual artery at its termination, near the frænum linguæ, is again comparatively superficial.

Branches.—(*a*) The **supra-hyoid** (ramus hyoideus), a small branch which arises in the carotid triangle and runs along the upper border of the great cornu of the hyoid bone. It anastomoses with its fellow of the opposite side and with the infrahyoid branch of the superior thyroid artery.

(*b*) The **dorsalis linguæ** (ramus dorsalis linguæ) is a branch of moderate size which arises from the second part of the artery. It ascends on the genio-hyo-glossus to the dorsum of the tongue, where it branches and anastomoses with its fellow of the opposite side round the foramen cæcum. It supplies the posterior part of the tongue as far back as the epiglottis, and sends branches backwards to the tonsil which anastomose with the tonsillar branches of the ascending palatine branch of the facial and with the ascending pharyngeal artery.

(*c*) A **sublingual branch** (a. sublingualis) arises at the lower part of the anterior border of the hyo-glossus muscle and runs forwards and upwards, between the mylo-hyoid and the genio-hyo-glossus, to the sublingual gland, which it supplies; it also supplies the mylo-hyoid, the genio-hyo-glossus, and the genio-hyoid muscles, and it anastomoses with its fellow of the opposite side, with the continuation of the lingual by a branch which it sends along the frænum linguæ, and through the mylo-hyoid muscle with the submental branch of the facial.

(3) **Facial Artery.**—The facial or external maxillary artery (a. maxillaris externa, Fig. 554) springs from the front of the external carotid immediately above the lingual, and terminates at the side of the nose, where it divides into lateral nasal and angular branches.

Course.—It commences in the carotid triangle and passes upwards and slightly forwards through the submaxillary triangle to the angle of the jaw. It then runs forwards as far as the anterior margin of the masseter, where it turns round the lower border of the body of the mandible, and is then continued upwards and inwards, in the face, to its termination.

Relations.—In the carotid triangle the artery, except just at its origin, which is beneath the anterior fibres of the sterno-mastoid muscle, is comparatively superficial. Its deep surface rests on the middle and superior constrictor muscles which separate it from the lower part of the tonsil. As it passes into the submaxillary triangle it is crossed by the stylo-hyoid muscle and by the posterior belly of the digastric. In the submaxillary triangle it is embedded in a groove in the posterior end of the submaxillary gland, and it is separated by the gland from the more superficially-situated facial vein. In the upper part of the submaxillary region the artery is just under cover of the ramus of the lower jaw.

Turning round the lower border of the body of the jaw, which it grooves slightly, the artery becomes more superficial than in any other part of its course, being covered only by platysma, fascia, and skin. At this point the facial vein is close behind the artery, and lies on the surface of the masseter. On the face the artery lies between the platsyma, the risorius, the zygomaticus major and the levator labii superioris, which, with skin and fascia, are superficial to it, and the buccinator and levator anguli oris, which are deeper. The termination of the artery is in the substance of the levator labii superioris et alæ nasi.

The facial vein, though still posterior to the artery in the face, runs a somewhat straighter course, and is situated at some little distance from it.

Branches.—Four named branches are given off in the neck, and seven in the face.

In the Neck.—(*a*) The **ascending palatine** (a. palatina ascendens, Fig. 556) is a small artery which arises from the facial as it enters the submaxillary triangle. It ascends under the internal pterygoid and upon the superior constrictor and, passing between the stylo-glossus and the stylo-pharyngeus muscles, reaches the apex of the petrous portion of the temporal bone, where it turns downwards accompanying the levator palati muscle, pierces the pharyngeal aponeurosis, and enters the soft palate.

It supplies the lateral wall of the upper part of the pharynx, the soft palate, the tonsils, and the Eustachian tube, and it anastomoses with the tonsillar branch of the facial, the dorsalis linguæ, the posterior palatine branch of the internal maxillary, and with the ascending pharyngeal artery which sometimes replaces it.

(*b*) The **tonsillar** (ramus tonsillaris), a small artery which arises close to the ascending palatine. It passes upwards between the internal pterygoid and the stylo-glossus, pierces the superior constrictor, and terminates in the tonsil. It supplies the middle and superior constrictor muscles, and it anastomoses with the dorsalis linguæ, with the ascending palatine branch, and with the ascending pharyngeal artery.

(*c*) The **submaxillary** or **glandular branch** is frequently represented by two or three small twigs (rami glandulares) which pass directly from the facial trunk into the substance of the submaxillary gland.

(*d*) The **submental branch** (a. submentalis) arises from the facial just as the latter vessel turns round the inferior border of the body of the jaw. It is the largest branch given off in the neck and it runs forwards, on the outer surface of the mylo-hyoid muscle and under the upper part of the submaxillary gland, to the symphysis menti, where it turns upwards round the margin of the jaw, and terminates by anastomosing with branches of the mental and inferior labial arteries. In the neck the submental artery supplies the mylo-hyoid muscle, and the submaxillary and sublingual glands, the latter by a branch which perforates the mylo-hyoid muscle. It anastomoses with the mylo-hyoid branch of the inferior dental and with the sublingual artery. In the face it supplies the structures of the lower lip, and anastomoses with the mental branch of the inferior dental, and with the inferior labial and inferior coronary branches of the facial artery.

In the Face.—(*e*) The **inferior labial branch** (a. labialis inferior) arises from the front of the facial artery immediately above the lower border of the mandible. It runs forwards beneath the depressor muscles of the angle of the mouth and the

lower lip, supplying the skin, muscles, and mucous membrane, and anastomoses with the mental branch of the inferior dental, with the inferior coronary, with the submental, and with its fellow of the opposite side.

(*f*) The **inferior coronary** springs from the front of the facial artery, either together with or directly above the inferior labial branch. It runs forwards beneath the depressor anguli oris, and between the fibres of the orbicularis oris and the mucous membrane of the lip. It supplies the adjacent parts, and anastomoses with its fellow of the opposite side, and with the mental, inferior labial, and submental arteries.

(*g*) The **superior coronary** (a. labialis superior) springs from the front of the facial beneath the zygomaticus major, and runs forwards and inwards between the orbicularis oris and the mucous membrane of the upper lip to the middle line. It supplies the skin, muscles, and mucous membrane of the upper lip, and the lower and front part of the septum of the nose, by a *septal branch* which runs upwards on the anterior part of the nasal septum. It anastomoses with its fellow of the opposite side, with the lateral nasal, and, on the septum nasi, with the naso-palatine branch of the spheno-palatine artery.

(*h*) The **masseteric branch**, sometimes represented by several twigs, arises from the posterior aspect of the facial trunk a short distance above the lower margin of the jaw. It passes upwards and backwards across the masseter, and anastomoses with the transverse facial artery.

(*i*) The **buccal** is an inconstant branch which, when present, arises from the back of the facial artery above the masseteric branch and runs upwards and backwards, across the buccinator muscle, to anastomose with the buccal branch of the internal maxillary artery.

(*k*) The **lateral nasal**, one of the terminal branches of the facial artery, is usually small. It ramifies on the ala of the nose, supplying the skin, muscles, and lower lateral cartilages, and anastomosing with the angular branch, with the nasal branch of the ophthalmic, and with branches of the spheno-palatine artery.

(*l*) The **angular** (a. angularis), the other terminal branch of the facial, continues the direction of the main trunk along the side of the nose to the inner angle of the orbit. It supplies the skin and muscles of the side of the nose, and anastomoses with the lateral nasal, and with the nasal and palpebral branches of the ophthalmic artery.

(4) **Occipital Artery** (a. occipitalis, Figs. 554, 555, and 582).—This vessel arises from the back of the external carotid artery, below the posterior belly of the digastric muscle, and terminates near the inner end of the superior curved line of the occipital bone by dividing into internal and external terminal branches.

Course.—It commences in the carotid triangle and runs upwards and backwards, parallel with and under cover of the posterior belly of the digastric, to the interval between the transverse process of the atlas and the base of the skull, where it turns backwards in a groove on the under surface of the mastoid portion of the temporal bone; as it leaves the groove it alters its direction and runs upwards and inwards on the superior oblique muscle to the junction of the inner and middle thirds of the superior curved line of the occipital bone, where it enters the superficial fascia of the scalp.

Relations.—In the first or ascending part of its course the occipital artery crosses successively the internal carotid artery, the hypoglossal nerve, the vagus nerve, the internal jugular vein, and the spinal accessory nerve; it is covered by the lower fibres of the posterior belly of the digastric and the anterior part of the sterno-mastoid muscle and, close to its origin, it is crossed by the hypoglossal nerve. In the second, or more horizontal part of its course, it is still under cover of the sterno-mastoid and digastric, and lies internally against the rectus capitis lateralis, which separates it from the vertebral artery. In the third part of its course it rests upon the superior oblique and complexus, and is under cover of the sterno-mastoid, the splenius capitis, and the trachelo-mastoid muscles. At its termination it is crossed by the great occipital nerve; it passes either through the trapezius or between the trapezius and the sterno-mastoid, and pierces the deep fascia of the neck before it enters the superficial fascia of the scalp.

Branches.—(*a*) **Muscular branches** (rami musculares) go to the surrounding muscles. The **sterno-mastoid branch** (a. sternocleido-mastoidea) is the most important of this group; it springs from the commencement of the occipital, is looped downwards across the hypoglossal nerve, and is continued downwards and backwards, below and in front of the spinal accessory nerve, into the sterno-mastoid muscle where it anastomoses with the sterno-mastoid branch of the superior thyroid artery.

(*b*) The **meningeal** are irregular branches (rami meningei) given off from the occipital

behind the mastoid process. They enter the posterior fossa of the skull through the anterior condyloid foramen, or through the foramen lacerum posterius; they supply the upper part of the internal jugular vein, the lateral sinus, and the dura mater in the posterior fossa of the skull, and they anastomose with the middle meningeal and with meningeal branches of the ascending pharyngeal artery.

(*c*) The **mastoid**, a small and irregular branch (ramus mastoideus) given off from the occipital behind the mastoid process. It enters the posterior fossa of the skull through the mastoid foramen, supplies the dura mater, and anastomoses with branches of the middle meningeal artery.

(*d*) The **princeps cervicis** (ramus descendens) is a large branch given off from the occipital upon the surface of the superior oblique. It passes inwards to the outer border of the complexus, where it divides into superficial and deep branches. The superficial branch runs over the complexus, between it and the trapezius, and anastomoses with the superficial cervical artery. The deep branch dips beneath the complexus into the sub-occipital triangle, where it anastomoses with branches of the vertebral and profunda cervicis arteries.

(*e*) The **auricular** (ramus auricularis) is an inconstant branch which, as a rule, is only given off from the occipital when the posterior auricular artery is absent. It ramifies over the mastoid process, and supplies the inner surface of the pinna.

(*f*) The **terminal branches** (rami occipitales) are internal and external. They ramify in the superficial fascia of the posterior part of the scalp, anastomosing with the posterior auricular and superficial temporal arteries. They are both accompanied by branches of the great occipital nerve, and the internal branch gives off a parietal twig, which passes into the skull through the parietal foramen to supply the walls of the superior longitudinal sinus, and to anastomose with the middle meningeal artery.

(5) **Posterior Auricular Artery** (a. auricularis posterior, Figs. 554, 555).—The posterior auricular artery springs from the back of the external carotid, immediately above the posterior belly of the digastric muscle, and terminates between the mastoid process and the back of the pinna by dividing into mastoid and auricular branches.

Course and relations.—Commencing in the posterior part of the submaxillary triangle, it runs upwards and backwards, under cover of the posterior part of the parotid gland, to the interval between the mastoid process and the external auditory meatus. It is accompanied in the terminal part of its course by the posterior auricular branch of the facial nerve.

Branches.—(*a*) **Muscular branches** are given to the sterno-mastoid, the digastric, and the styloid group of muscles.

(*b*) **Parotid branches** pass to the lower and posterior part of the parotid gland.

(*c*) A **stylo-mastoid branch** (a. stylomastoidea) is given off at the lower border of the external auditory meatus. It runs upwards by the side of the facial nerve, enters the stylo-mastoid foramen, and ascends, in the aqueduct of Fallopius, to the upper part of the inner wall of the tympanum where it terminates by anastomosing with the petrosal branch of the middle meningeal artery. It supplies branches to the external auditory meatus, the mastoid cells, the vestibule, and semicircular canals, the stapedius muscle, and the tympanic cavity (a. tympanica posterior). One of the latter branches, anastomosing with the tympanic branch of the internal maxillary, forms, in young subjects, a vascular circle round the membrana tympani; other branches anastomose with tympanic branches from the internal carotid and the ascending pharyngeal arteries, and with the auditory branch of the basilar.

(*d*) The **auricular,** or anterior terminal branch (ramus auricularis), ascends beneath the retrahens aurem muscle. It gives branches to the scalp in the posterior part of the temporal region, which anastomose with the superficial temporal and occipital arteries, and to the pinna. The latter branches supply both surfaces of the pinna, piercing or turning round the margins of the cartilage to gain the outer surface, and they anastomose with the auricular branches of the superficial temporal artery.

(*e*) The **mastoid,** or posterior terminal branch (ramus occipitalis), runs upwards and backwards along the insertion of the sterno-mastoid muscle. It supplies the sterno-mastoid, the occipito-frontalis, and the skin, and it anastomoses with the occipital artery.

(6) **Ascending Pharyngeal Artery** (a. pharyngea ascendens, Fig. 556).—This

arises from the inner surface of the lower part of the external carotid, and terminates in the wall of the pharynx and in the soft palate.

Course.—Commencing in the carotid triangle, usually as the first or second branch of the external carotid, it ascends on the wall of the pharynx to the apex of the petrous portion of the temporal bone.

Relations.—Internally it is in relation with the constrictor muscles of the pharynx. Behind it are the transverse processes of the cervical vertebræ, the sympathetic cord, and the rectus capitis anticus major. Externally it is in relation with the internal carotid artery, and it is crossed by the stylo-pharyngeus muscle, the glosso-pharyngeal nerve, and the pharyngeal branch of the vagus.

Branches.—The branches of this artery are very irregular and inconstant, but the following have received names :—

(*a*) **Pharyngeal Branches** (rami pharyngei).—Small twigs which ramify on the walls of the pharynx and supply the middle and superior constrictor muscles, the tonsil, and the lower part of the Eustachian tube. They anastomose with branches of the superior thyroid, lingual, and facial arteries.

(*b*) **Prevertebral.**—Small branches distributed to the prevertebral muscles and fascia, the deep cervical glands, and the large nerve trunks. They anastomose with the ascending cervical and vertebral arteries.

(*c*) **Meningeal** (a. meningea posterior) one or more small branches which enter the cranium by the anterior condyloid, the posterior lacerate, or the middle lacerate foramen, and supply the dura mater. They anastomose with branches of the middle meningeal and vertebral arteries.

(*d*) **Tympanic** (a. tympanica inferior), a small artery which accompanies the tympanic branch of the glosso-pharyngeal nerve to the tympanic cavity, where it anastomoses with the other tympanic arteries.

(*e*) **Palatine.**—A very variable artery which sometimes replaces the ascending palatine branch of the facial artery. When present it springs from the upper part of the ascending pharyngeal artery, pierces the pharyngeal aponeurosis above the upper border of the superior constrictor muscle, and descends into the soft palate with the levator palati muscle. It supplies the mucous membrane of the supero-lateral part of the pharyngeal wall and the tissues of the soft palate, and it anastomoses with the palatine branches of the internal maxillary, the facial, and the lingual arteries.

(7) **Superficial Temporal Artery** (a. temporalis superficialis, Fig. 554).—This artery, one of the terminal branches of the external carotid, commences in the upper part of the parotid gland, behind the neck of the mandible, and terminates in the scalp, from one to two inches (25 to 50 mm.) above the zygoma, by dividing into an anterior and a posterior terminal branch.

Course.—The artery ascends over the posterior root of the zygoma, and passes into the superficial fascia of the temporal region. It is accompanied by the auriculo-temporal nerve, and by the superficial temporal vein which usually lies posterior to it. As it crosses the zygoma it lies immediately beneath the skin, and it may be easily compressed against the subjacent bone.

Branches.—(*a*) **Parotid**, small branches (rami parotidei) to the upper part of the parotid gland.

(*b*) **Articular**, to the temporo-mandibular articulation.

(*c*) **Auricular.**—Small branches (rami auriculares anteriores) to the outer surface of the pinna and to the external auditory meatus. They anastomose on the surface of the pinna with branches of the posterior auricular artery, and in the external meatus with branches of the internal maxillary artery.

(*d*) **Transverse Facial** (a. transversa faciei).—A branch of moderate size which rises in the substance of the parotid gland. It emerges from the upper part of the anterior border of the gland, runs forwards across the masseter, below the zygoma and above Stenson's duct, accompanied by the infraorbital branches of the facial nerve which may lie either above or below it. It is distributed to the parotid gland, the masseter, Stenson's duct, and the skin, and it terminates in branches which anastomose with the infraorbital and buccal branches of the internal maxillary artery, and with the buccal and masseteric branches of the facial artery.

(*e*) **Middle Temporal** (a. temporalis media).—A branch which usually springs from the superficial temporal in the parotid gland. It crosses the zygoma, pierces the temporal

fascia and the temporal muscle, and terminates in the temporal fossa by anastomosing with the deep temporal branches of the internal maxillary artery.

(*f*) **Orbital** (a. zygomatico-orbitalis).—This branch may spring directly from the superficial temporal, but it is frequently a branch of the middle temporal. It runs forwards above the zygoma between the two layers of the temporal fascia. It supplies branches to the orbicularis palebrarum, and anastomoses, through the malar bone and round the outer margin of the orbit, with the lachrymal and palpebral branches of the ophthalmic artery.

(*g*) The **anterior terminal branch** (ramus frontalis) runs forwards and upwards, in a tortuous course, through the superficial fascia of the scalp towards the frontal eminence, lying at first upon the temporal fascia, and then upon the epicranial aponeurosis. It supplies the frontalis and the orbicularis palpebrarum, and anastomoses with the lachrymal

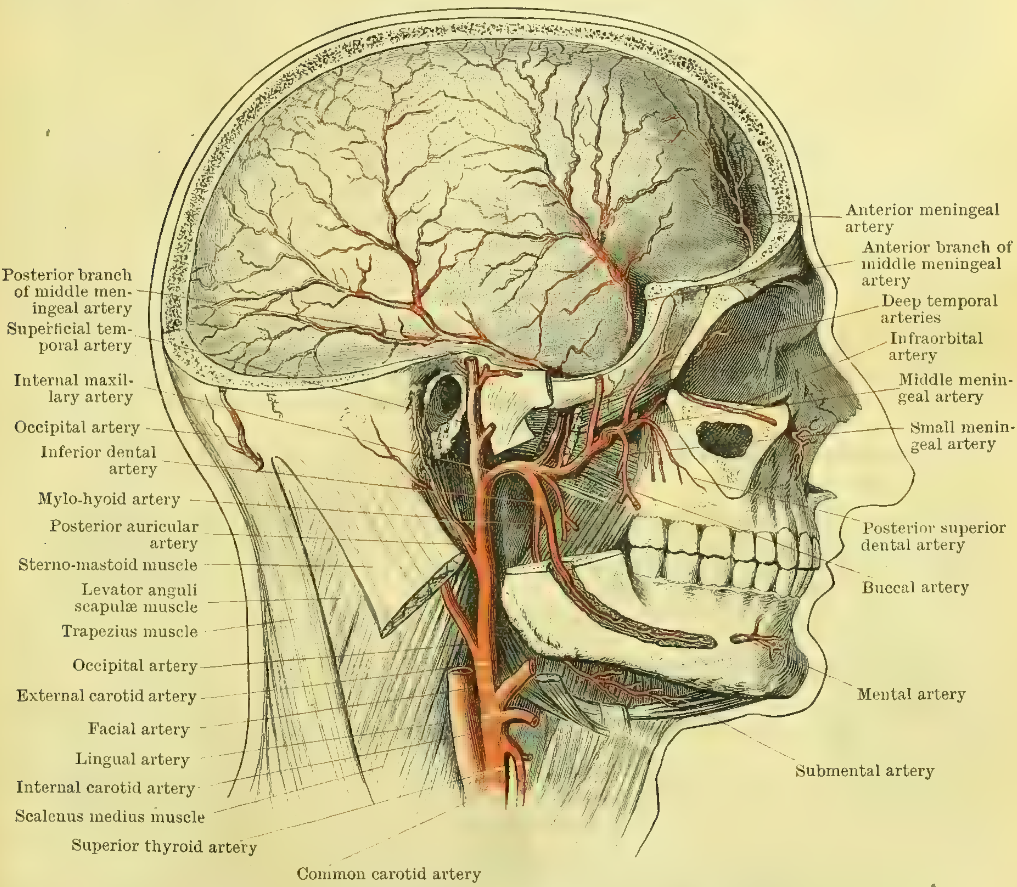


FIG. 555.—THE EXTERNAL CAROTID, INTERNAL MAXILLARY, AND MENINGEAL ARTERIES.

and supraorbital branches of the ophthalmic artery, with the posterior terminal branch of the superficial temporal, and with its fellow of the opposite side.

(*h*) The **posterior terminal branch** (ramus parietalis), less tortuous than the anterior, runs upwards and backwards in the superficial fascia of the scalp. It anastomoses, anteriorly, with the anterior terminal branch, posteriorly with the posterior auricular and occipital arteries, and, across the middle line, with its fellow of the opposite side. It supplies the skin and fascia, and the attrahens and attollens aurem muscles.

(8) **Internal Maxillary Artery** (a. maxillaris interna).—The internal maxillary artery commences in the parotid gland behind the neck of the lower jaw, and terminates in the spheno-maxillary fossa.

Course and Relations.—Although the internal maxillary artery is only a short trunk it has many important relations, in the consideration of which it is convenient to arbitrarily divide the vessel into three parts. The **first part** extends from the back of the neck of the mandible forwards into the zygomatic fossa as

far as the lower border of the external pterygoid muscle. It lies between the spheno-mandibular ligament and the neck of the jaw, along with the auriculo-temporal nerve and the internal maxillary vein. The **second part** is in the zygomatic fossa, and ascends upwards and forwards. It may lie superficial to, or under cover of, the lower head of the external pterygoid muscle. In the former case it is situated between the temporal and external pterygoid muscles, and in the latter between the external pterygoid muscle and the branches of the third division of the fifth nerve. The **third part** passes between the upper and the lower heads of the external pterygoid, through the pterygo-maxillary fissure and into the spheno-maxillary fossa.

Branches.—*From the first part.*—(*a*) **Deep auricular** (a. auricularis profunda), a small branch which rises in the parotid gland and passes upwards to enter the external auditory meatus. It supplies the temporo-mandibular joint, the parotid gland, and the external meatus, and anastomoses with branches of the superficial temporal and posterior auricular arteries.

(*b*) The **tympanic** (a. tympanica anterior), a variable and small branch which commences in the parotid gland. It runs upwards and backwards, traverses the Glasserian fissure, and enters the tympanum through its outer wall. In the tympanic cavity it anastomoses with tympanic branches from the internal carotid and the ascending pharyngeal arteries, and with the stylo-mastoid branch of the posterior auricular, forming with the latter, in young subjects, a circular anastomosis round the tympanic membrane.

(*c*) **Middle Meningeal** (a. meningea media).—The largest branch of the internal maxillary. It ascends between the external pterygoid muscle and the spheno-mandibular ligament, and passes between the two roots of the auriculo-temporal nerve and through the foramen spinosum, to enter the middle fossa of the cranial cavity. Before it enters the skull it lies behind the third division of the fifth nerve, and is accompanied by two venæ comites which also pass through the foramen spinosum. In the middle cranial fossa it passes forward and upwards for a short distance, in a groove on the great wing of the sphenoid, between the dura mater and the bone, and divides into anterior and posterior terminal branches

Branches.—(i.) **Petrosal** (ramus petrosus superficialis).—A small branch which arises from the middle meningeal soon after it enters the cranium. It passes through the hiatus Fallopii and anastomoses with the stylo-mastoid branch of the posterior auricular artery; it also sends some small branches into the tympanic cavity.

(ii.) **Gasserian.**—Minute branches which supply the Gasserian ganglion and the roots of the fifth cranial nerve.

(iii.) **Tympanic** (a. tympanica superior).—A small twig which reaches the tympanic cavity through the canal for the tensor tympani muscle, or through the petro-squamous suture.

(iv.) **Orbital.**—An anastomosing branch which occasionally arises from the anterior terminal branch. It passes through the foramen lacerum anterius into the orbit, and anastomoses with the lachrymal artery.

(v.) **Anterior terminal**, the larger of the two terminal branches, passes upwards along the great wing of the sphenoid to the antero-inferior angle of the parietal bone, where it is sometimes enclosed in a distinct bony canal; it is continued upwards a short distance behind the anterior border of the parietal bone almost to the vertex of the skull, sending branches forwards into the anterior, and backwards towards the posterior cranial fossa.

(vi.) The **posterior terminal branch** passes backwards from the great wing of the sphenoid to the squamous part of the temporal bone, beyond which it ascends to the middle of the inner surface of the parietal bone. It sends branches upwards to the vertex, and backwards towards the posterior cranial fossa.

By means of its various branches the middle meningeal artery anastomoses with its fellow of the opposite side, with meningeal branches from the occipital, ascending pharyngeal, ophthalmic, and lachrymal arteries; also with the stylo-mastoid branch of the posterior auricular, the small meningeal artery, with the deep temporal arteries through the substance of the temporal bone, and with its fellow of the opposite side.

(*d*) A **small meningeal branch** (ramus meningeus accessorius) may arise either directly from the first part of the internal maxillary or from its middle meningeal branch. It passes upwards, on the inner side of the external pterygoid muscle, enters the middle fossa of the skull through the foramen ovale, supplies the Gasserian ganglion and the dura mater, and terminates by anastomosing with branches of the middle meningeal artery.

(*e*) The **inferior dental** (a. alveolaris inferior) is a branch of moderate size which passes downwards between the spheno-mandibular ligament and the mandible to the mandibular foramen. It is accompanied by the inferior dental nerve which lies in front.

After entering the foramen it descends in the mandibular canal, and terminates at the mental foramen by dividing into mental and incisive branches.

Branches.—Before it enters the mandibular foramen it gives off two branches.

(i.) The **lingual,** a small twig to the buccal mucous membrane which accompanies the lingual nerve. (ii.) The **mylo-hyoid** (ramus mylohoideus), a small branch which is given off immediately above the mandibular foramen. It pierces the spheno-mandibular ligament, and descends in the mylo-hyoid groove, in company with the mylo-hyoid nerve, to the floor of the mouth, where it anastomoses, on the superficial surface of the mylo-hyoid muscle, with the submental branch of the facial artery.

In the mandibular canal the following branches are given off:—

(i.) **Molar branches** to the molar teeth. (ii.) **Bicuspid branches** to the bicuspid teeth. (iii.) The **incisive terminal branch,** which supplies the incisor teeth and anastomoses with its fellow of the opposite side. (iv.) The **mental terminal branch** (a. mentalis), which passes through the mental foramen, emerges beneath the depressor labii inferioris, and anastomoses with its fellow of the opposite side, with the inferior coronary, the inferior labial, and with the submental arteries.

From the second part.—(*a*) The **masseteric** (a. masseterica), a small branch which passes directly outwards, through the sigmoid notch, to the deep surface of the masseter muscle. It anastomoses in the substance of the muscle with branches of the transverse facial and with the masseteric branches of the facial artery.

(*b*) **Deep Temporal.**—Two in number, anterior (a. temporalis profunda anterior) and posterior (a. temporalis profunda posterior). They ascend between the temporal muscle and the squamous portion of the temporal bone, supplying the muscle and anastomosing with the temporal and lachrymal arteries, and, through the substance of the temporal bone, with the middle meningeal artery.

(*c*) Small **pterygoid branches** (rami pterygoidei) supply the internal and external pterygoid muscles.

(*d*) The **buccal** (a. buccinatoria), a long slender branch which passes obliquely forwards and downwards with the long buccal nerve. It supplies the buccinator muscle, the skin and mucous membrane of the cheek, and anastomoses with the buccal branch of the facial artery.

From the third part.—(*a*) A **posterior superior dental branch** (a. alveolaris superior posterior) descends in the zygomatic fossa, on the posterior surface of the superior maxilla, and ends in branches which supply the molar and bicuspid teeth and the mucous membrane of the antrum, they also give twigs to the gums and to the buccinator muscle.

(*b*) An **infraorbital branch** (a. infraorbitalis) commences in the spheno-maxillary fossa. It enters the orbit through the spheno-maxillary fissure, and runs forwards in the infraorbital groove and canal to the infraorbital foramen, through which it passes to emerge on the face beneath the levator labii superioris. Whilst in the infraorbital groove it gives branches to the inferior rectus, the inferior oblique and the lachrymal gland. In the infraorbital canal it gives small twigs to the incisor and canine teeth (aa. alveolares superiores anteriores) and to the antrum. In the face it sends branches upwards to the lower eyelid, to the lachrymal sac, and to the nasal process of the superior maxilla, which anastomose with branches of the ophthalmic and facial arteries; other branches run downwards to the upper lip, where they anastomose with the superior coronary artery; lastly, some branches run outwards into the cheek to unite with the transverse facial and the buccal arteries.

(*c*) The **posterior** or **descending palatine** (a. palatina descendens) runs downwards through the spheno-maxillary fossa, passes through the posterior palatine canal and reaches the mucous membrane of the roof of the mouth, where it runs forwards, internal to the alveolar process, to terminate in a small branch which ascends through the anterior palatine fossa and Stenson's canal, and anastomoses with the spheno-palatine branch of the internal maxillary artery. As it descends it gives off several small twigs which pass through the accessory palatine canals to supply the soft palate and to anastomose with the ascending palatine and tonsillar branches of the facial and with the ascending pharyngeal artery. In its course forwards in the roof of the mouth it supplies the gums and the mucous membrane of the hard palate, and also the palate and superior maxillary bones.

(*d*) The **Vidian** (a. canalis pterygoidei) is a long slender branch which runs backwards through the Vidian canal with the Vidian nerve. It supplies branches to the upper part of the pharynx, to the levator and tensor palati muscles, and to the Eustachian tube. One of the latter branches passes along the wall of the Eustachian tube to the tympanic cavity, where it anastomoses with the other tympanic arteries.

(*e*) The **pterygo-palatine** is a small artery which runs backwards, with the pharyngeal branch of Meckel's ganglion, to the roof of the pharynx. It supplies the upper and back

part of the roof of the nose, the roof of the pharynx, the sphenoidal sinus, and the lower part of the Eustachian tube, and anastomoses with the Vidian branch of the internal carotid.

(*f*) The **spheno-palatine branch** (a. spheno-palatina) springs from the termination of the internal maxillary artery. It passes inwards through the spheno-palatine foramen into the nasal cavity, where it divides into many branches. One of these, the internal nasal or **naso-palatine**, which is sometimes looked upon as the continuation of the artery, crosses the back part of the roof of the nose, and descends in a groove on the vomer to the incisive foramen where it anastomoses with the termination of the posterior palatine artery and with the septal branch of the superior coronary. The outer or external nasal branches of the spheno-palatine artery supply the greater part of the outer wall of the nasal fossa and the cavity of the antrum, anastomosing with branches of the infraorbital, ethmoidal, and lateral nasal arteries. Branches are also distributed to the ethmoidal cells, to the sphenoidal sinus, and to the upper part of the pharynx.

THE INTERNAL CAROTID ARTERY

The **internal carotid artery** (a. carotis interna, Figs. 554, 556, and 559) commences at the termination of the common carotid, opposite the upper border of the

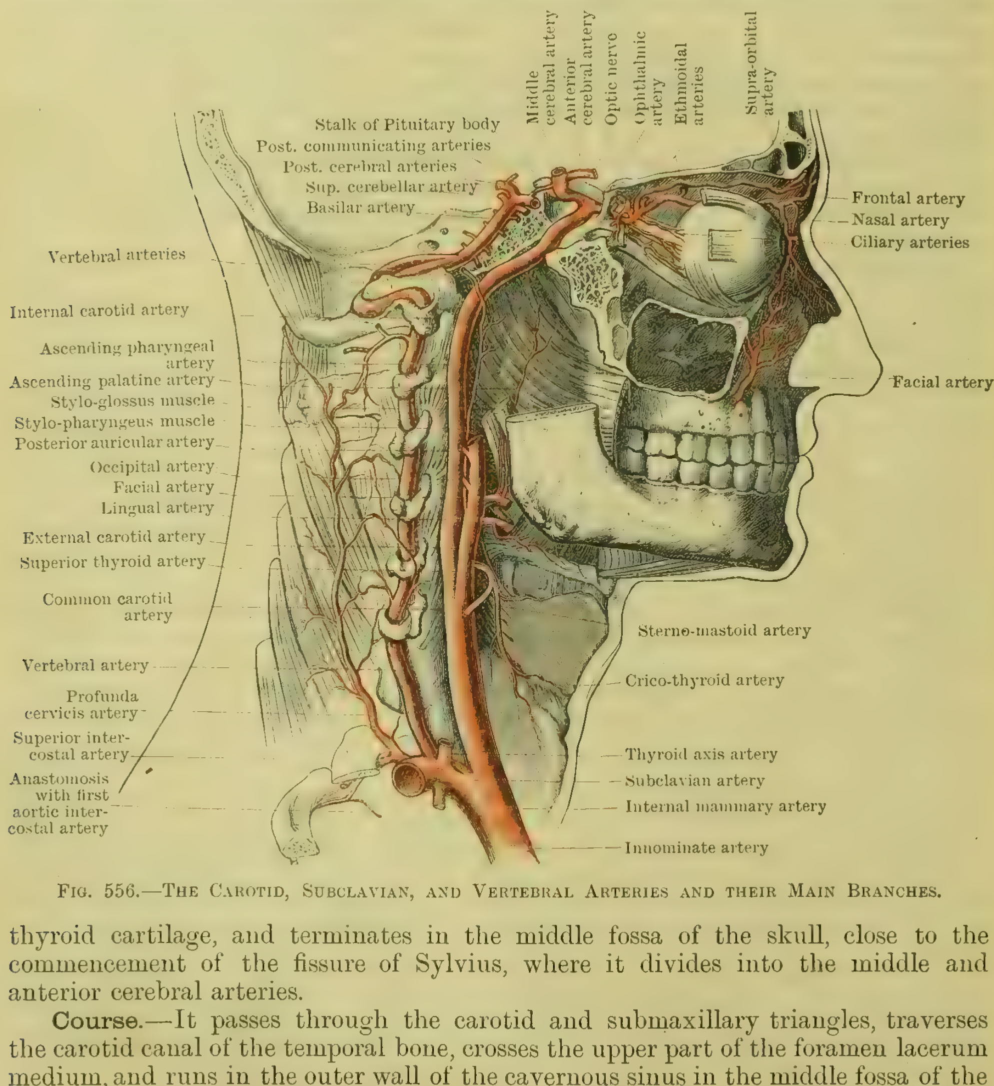


FIG. 556.—THE CAROTID, SUBCLAVIAN, AND VERTEBRAL ARTERIES AND THEIR MAIN BRANCHES.

thyroid cartilage, and terminates in the middle fossa of the skull, close to the commencement of the fissure of Sylvius, where it divides into the middle and anterior cerebral arteries.

Course.—It passes through the carotid and submaxillary triangles, traverses the carotid canal of the temporal bone, crosses the upper part of the foramen lacerum medium, and runs in the outer wall of the cavernous sinus in the middle fossa of the skull.

At its origin it lies behind and to the outer side of the external carotid, but as

it ascends beneath the posterior belly of the digastric and the stylo-hyoid, it gets to the inner side of that vessel. After entering the submaxillary triangle it ascends, in relation with the posterior surface of the parotid gland, to the carotid canal in the temporal bone, through which it passes to the apex of the petrous portion of the temporal bone, where it turns upwards, through the upper part of the foramen lacerum medium, into the middle cranial fossa. It then runs forwards in the outer wall of the cavernous sinus to the lower root of the small wing of the sphenoid, where it turns upwards and then backwards and outwards to its termination.

Relations.—The relations of the various parts of the artery require separate consideration.

In the neck.—Posterior.—The rectus capitis anticus major, the prevertebral fascia and the sympathetic cord, separate it from the transverse processes of the cervical vertebræ, and somewhat to its outer side are the internal jugular vein and the vagus nerve. The spinal accessory and the glosso-pharyngeal nerves are also behind and to the outer side of the artery in the upper part of the neck, and they intervene between it and the internal jugular vein. *Internal* or deep to the internal carotid is the external carotid artery for a short distance below, and afterwards the wall of the pharynx, the ascending pharyngeal artery, the pharyngeal plexus of veins, and the external and internal laryngeal nerves. Just before it enters the temporal bone the levator palati muscle is to its inner side. *External* or superficial to it are the sterno-mastoid, skin, and fascia, and it is crossed beneath the sterno-mastoid from below upwards by the hypoglossal nerve, the occipital artery, and the posterior auricular artery. It is also crossed more superficially by the digastric and stylo-hyoid muscles, and in the upper part of its extent it is covered by the posterior part of the parotid gland. Passing obliquely across its anterior and outer surface, and separating it from the external carotid artery, are the following structures, viz.: the stylo-pharyngeus, the tip of the styloid process or the stylo-glossus muscle, the glosso-pharyngeal nerve, the pharyngeal branch of the vagus, and some sympathetic twigs.

In the carotid canal.—The artery, as it passes upwards and inwards, is in front of and below the cochlea and the tympanum; behind and internal to the canals for the Eustachian tube and the tensor tympani; and below the Gasserian ganglion. The thin lamina of bone which separates it from the tympanum is frequently perforated, and that between it and the Gasserian ganglion is not infrequently absent. In its course through the canal it is accompanied by small veins and nerves. The veins are tributaries from the tympanum, which communicate above with the cavernous sinus and below with the internal jugular vein. The nerves are the upward continuations of the sympathetic cord; they form two plexuses—one on the outer side of the artery, the carotid plexus, and one on the inner side, the cavernous plexus.

As it enters the cavity of the cranium the internal carotid artery pierces the external layer of the dura mater and passes between the lingula and the sixth cranial nerve externally, and the posterior petrosal process of the body of the sphenoid internally.

In the cranial cavity.—The artery runs forwards in the outer wall of the cavernous sinus in relation with the third, fourth, the ophthalmic division of the fifth, and the sixth cranial nerves externally, and with the endothelial wall of the sinus internally. When it reaches the lower root of the small wing of the sphenoid it turns upwards to the inner side of the anterior clinoid process, pierces the inner layer of the dura mater, and comes into close relation with the under surface of the optic nerve immediately behind the optic foramen. It then turns abruptly backwards beneath the optic nerve, and on the inner side of the anterior clinoid process which it frequently grooves; inclining outwards, it runs between the second and third nerves, and beneath the anterior perforated space, to the inner end of the stem of the Sylvian fissure, where it turns upwards, at some distance from the outer side of the optic chiasma, and, after piercing the arachnoid, divides into its two terminal branches, the anterior and middle cerebral arteries.

Branches of the Internal Carotid Artery.

Branches are given off from the internal carotid in the temporal bone and in the cranium, but, as a rule, no branches are given off in the neck.

In the temporal bone.—(1) A **tympanic branch** (ramus carotico-tympanicus), very small, perforates the posterior wall of the carotid canal, and anastomoses in the tympanum with the stylo-mastoid artery and with the tympanic branches of the internal maxillary and ascending pharyngeal arteries.

(2) The **Vidian** is a small and inconstant branch which accompanies the great deep petrosal nerve in the Vidian canal; it anastomoses with the Vidian branch of the internal maxillary artery.

In the cranium.—(1) **Cavernous**, small branches to the walls of the cavernous sinus and to the third, fourth, fifth, and sixth nerves.

(2) **Gasserian**, minute twigs which supply the Gasserian ganglion.

(3) **Pituitary branches** pass to the pituitary body.

(4) **Meningeal branches** ramify in the dura mater of the middle cranial fossa, anastomosing with the branches of the middle and small meningeal arteries.

(5) **Ophthalmic Artery** (a. ophthalmica, Fig. 556).—This artery springs from the front and inner side of the internal carotid as it turns upwards on the inner side of the anterior clinoid process. It passes forwards and outwards, beneath the optic nerve and through the optic foramen into the orbital cavity. In the orbit it runs forwards for a short distance on the outer side of the optic nerve, and it is in relation externally with the lenticular ganglion and the external rectus muscle; turning upwards and inwards, it crosses between the optic nerve and

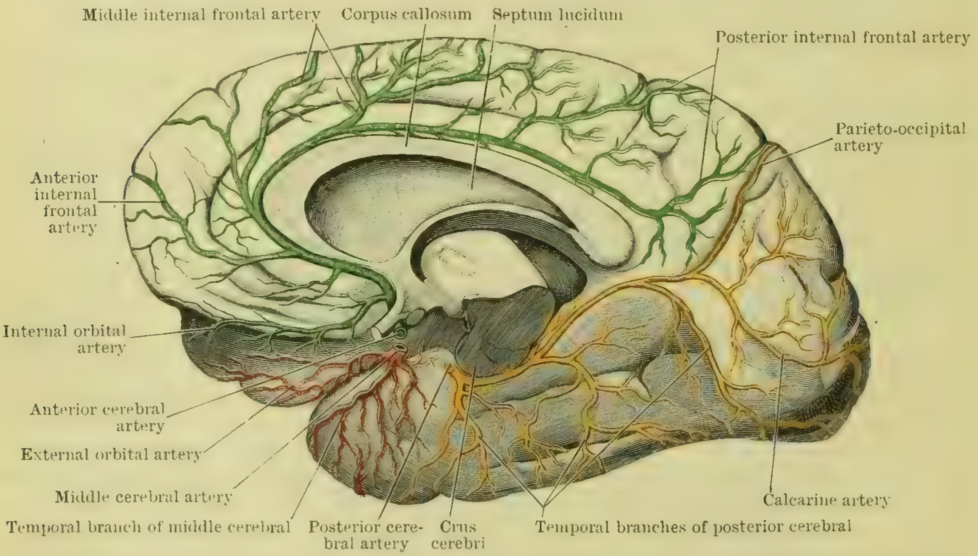


FIG. 557.—DISTRIBUTION OF THE CEREBRAL ARTERIES ON THE MESIAL, TENTORIAL, AND INFERIOR SURFACES OF THE CEREBRAL HEMISPHERES.

The anterior cerebral artery is coloured green, the middle cerebral artery red, and the posterior cerebral artery orange.

the superior rectus to the inner wall of the orbit, where it turns forwards to terminate at the inner and front part of the orbital cavity by dividing into frontal and nasal branches. It is accompanied at first by the nasal nerve, and in the terminal part of its course by the infra-trochlear nerve.

Branches.—The branches of the ophthalmic artery are numerous. (*a*) The **posterior ciliary**, usually six to eight in number, run forwards at the sides of the optic nerve; they soon divide into numerous branches which pierce the back part of the sclerotic coat; the majority terminate in the choroid coat of the eye as the *short ciliary arteries* (aa. ciliares posteriores breves), but two of larger size, the *long ciliary arteries* (aa. ciliares posteriores longæ), run forwards, one on each side, almost in the horizontal plane of the eyeball, between the sclerotic and the choroid coats, to the base of the iris, where they divide. The resulting branches anastomose together and form a circle at the outer periphery of the iris, from which secondary branches run inwards and anastomose together in a second circle near the inner margin of the iris.

(*b*) The **central artery of the retina** (a. centralis retinæ) arises near to, or in common with, the preceding vessels. It pierces the inner and under side of the optic nerve about half-an-inch (12 mm.) behind the sclera, and runs in its centre to the retina, where it breaks up into terminal branches.

(*c*) **Recurrent** (a. meningea anterior).—A small branch which passes backwards through the sphenoidal fissure into the middle fossa of the cranium, where it anastomoses with the middle and small meningeal arteries, and with the meningeal branches of the internal carotid and lachrymal arteries.

(*d*) The **lachrymal artery** (a. lacrimalis), arises from the ophthalmic on the outer side of the optic nerve. It runs forwards along the upper border of the external rectus to the upper and outer angle of the orbit, and in its course gives off branches to the lachrymal gland, muscular branches to the external and superior recti, palpebral branches to the upper eyelid and the upper and outer part of the forehead, temporal and malar branches, which accompany the temporal and malar branches of the temporo-malar nerve, to the face and the temporal fossa respectively; *anterior ciliary branches* (aa. ciliares anteriores), which perforate the sclera behind the corneo-scleral junction and anastomose with the posterior ciliary arteries; and a recurrent meningeal branch, which passes backwards through the outer part of the sphenoidal fissure to anastomose in the middle fossa of the skull with the middle meningeal artery.

(*e*) **Muscular.**—These branches are usually arranged in two sets, outer and inner. The former supply the upper and outer, and the latter the lower and inner orbital muscles. They anastomose with muscular branches from the lachrymal and the supra-orbital vessels, and they give off *anterior ciliary branches.*

(*f*) The **supra-orbital branch** (a. supra-orbitalis) is given off as the ophthalmic artery crosses above the optic nerve. It passes round the inner borders of the superior rectus and levator palpebræ muscles, and runs forwards between the latter and the periosteum to the supra-orbital notch, accompanying the frontal and supra-orbital nerves. Passing through the notch it reaches the scalp, and, perforating the frontalis muscle, anastomoses with the superficial, temporal, and frontal arteries.

(*g*) **Ethmoidal branches**, anterior (a. ethmoidalis anterior) and posterior (a. ethmoidalis posterior), arise from the ophthalmic as it runs forwards along the inner boundary of the orbital

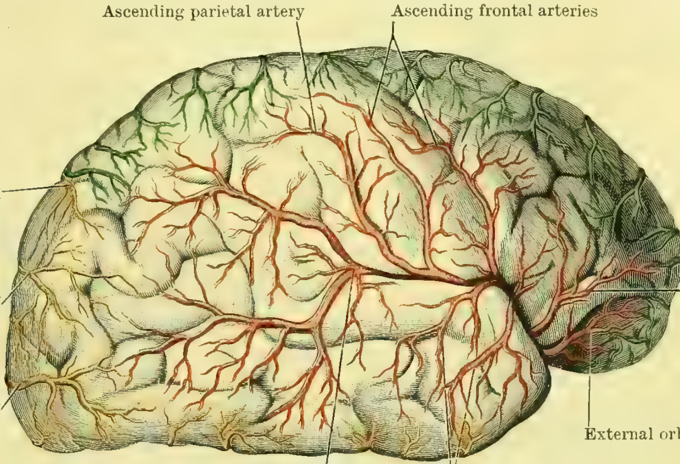


FIG. 558.—DISTRIBUTION OF CEREBRAL ARTERIES ON THE OUTER SURFACE OF THE CEREBRUM.
Anterior cerebral artery is coloured green, the middle cerebral red, and the posterior cerebral orange.

cavity. They pass inwards between the superior oblique and the internal rectus. The posterior, which is much the smaller of the two, traverses the posterior ethmoidal canal, and supplies the posterior ethmoidal cells and the posterior and upper part of the outer wall of the nasal cavity. The anterior ethmoidal artery passes through the anterior ethmoidal canal with the nasal nerve, enters the anterior fossa of the skull, and crosses the cribriform plate of the ethmoid to the nasal notch, through which it reaches the nasal cavity, where it descends with the nasal nerve in a groove on the back of the nasal bone, and finally passes between the upper lateral cartilage and the lower border of the nasal bone to the tip of the nose. It supplies branches to the membranes of the brain in the anterior cranial fossa as well as to the anterior ethmoidal cells, the frontal sinus, the anterior and upper part of the nasal mucous membrane, and the skin on the dorsum of the nose.

(*h*) **Palpebral branches** (aa. palpebrales), upper and lower, are given off near the termination of the ophthalmic. They are distributed to the upper and lower eyelids, and they anastomose with the lachrymal, supra-orbital, and infra-orbital arteries.

(*i*) The **nasal terminal branch** (a. dorsalis nasi) passes out of the orbit above the internal tarsal ligament. It pierces the palpebral fascia, and terminates on the side of the nose by anastomosing with the angular branch of the facial artery.

(*k*) The **frontal terminal branch** (a. frontalis) pierces the palpebral fascia at the upper and inner part of the orbit, and ascends, with the supra-trochlear nerve, in the superficial fascia of the anterior and mesial part of the scalp, anastomosing with its fellow of the opposite side and with the supra-orbital artery.

(6) The **posterior communicating artery** (a. communicans posterior) rises from the internal carotid near its termination. It runs backwards below the optic tract and in

front of the crus cerebri, and passing above the third nerve, joins the posterior cerebral artery forming part of the circle of Willis. It gives branches to the optic tract, the crus cerebri, the interpeduncular region, and the uncinate convolution of the brain. The posterior communicating artery varies much in size; it may be small on one or both sides, sometimes it is very large on one side; occasionally it replaces the posterior cerebral artery, and it sometimes arises from the middle cerebral artery.

(7) The **anterior chorioidal** (a. chorioidea) is a small branch, which also rises near the termination of the internal carotid; it passes backwards and outwards, between the crus cerebri and the uncinate convolution, to the lower and front part of the chorioidal fissure which it enters, and it terminates in the chorioidal plexus in the descending cornu of the lateral ventricle. It supplies the optic tract, the crus cerebri, the uncinate convolution, and the posterior part of the internal capsule.

(8) **Anterior Cerebral Artery** (a. cerebri anterior). This is the smaller of the two terminal branches of the internal carotid. It passes forwards and inwards, above the optic chiasma and immediately in front of the lamina cinerea, to the commencement of the great longitudinal fissure, where it turns round the genu of the corpus callosum, and runs backwards to the parietal lobe of the brain. At the commencement of the great longitudinal fissure it is closely connected with its fellow of the opposite side by a wide but short **anterior communicating artery** (a. communicans anterior), and in the remainder of its course it is closely accompanied by its fellow artery of the opposite side.

Branches.—Branches of all the cerebral arteries are distributed both to the basal ganglionic masses of the brain and to the cerebral cortex; they therefore form two distinct groups—(*a*) **central or ganglionic**; (*b*) **cortical.**

The branches of the anterior cerebral include:

(*a*) *Central or ganglionic branches.*—The **antero-mesial arteries**, a small group of vessels, constitute the central branches of the anterior cerebral artery; they pass upwards into the base of the brain in front of the optic chiasma, and supply the rostrum of the corpus callosum, the lamina cinerea, and the septum lucidum.

(*b*) *Cortical branches.* — (b^1) **Internal orbital**, one or more small branches which supply the internal orbital convolution, the gyrus rectus, and the olfactory lobe.

(b^2) **Anterior internal frontal**, one or more branches which are distributed to the anterior and lower part of the marginal convolution, and to the anterior portions of the superior and middle frontal convolutions.

(b^3) A **middle internal frontal** is distributed to the posterior part of the marginal convolution, and to the upper portions of the superior and ascending frontal and ascending parietal convolutions.

(b^4) The **posterior internal frontal** runs backwards to the quadrate lobule. It supplies the corpus callosum, the quadrate lobe, and the upper part of the superior parietal lobule.

(9) **Middle Cerebral Artery** (a. cerebri media).—The middle cerebral is the larger of the two terminal branches, and the more direct continuation of the internal carotid artery. It passes outwards in the fissure of Sylvius to the outer surface of the island of Reil, which it crosses; and divides, in the posterior limiting sulcus of Reil, into parieto-temporal and temporal terminal branches.

Branches.—(*a*) *Central or ganglionic.*—Numerous and very variable in size. These branches are given off at the base of the brain, in the region of the anterior perforated space. Two sets, known as the internal and the external striate arteries, are distinguishable.

(a^1) The **internal striate arteries** pass upwards through the two inner segments of the lenticular nucleus (globus pallidus) and the internal capsule to terminate in the caudate nucleus. They supply the anterior portions of the lenticular and caudate nuclei and of the internal capsule.

(a^2) The **external striate arteries** pass upwards through the outer segment (putamen) of the lenticular nucleus, or between it and the external capsule, and they form two sets, an anterior, the lenticulo-striate, and a posterior, the lenticulo-optic; both sets traverse the lenticular nucleus and the internal capsule, but the *lenticulo-striate arteries* terminate in the caudate nucleus, and the *lenticulo-optic* in the optic thalamus. One of the lenticulo-striate arteries, which passes in the first instance round the outer side of the lenticular nucleus, and afterwards through its substance, is larger than its companions; it frequently ruptures, and is known as the artery of cerebral hæmorrhage.

(*b*) *Cortical branches* are given off as the middle cerebral artery passes over the surface of the island of Reil at the bottom of tbe Sylvian fissure, as follows :—

(b^1) The **inferior external orbital** runs forwards and outwards, and is distributed to the outer part of the orbital surface of the frontal lobe and to the inferior frontal convolution.

(b^2) The **ascending frontal branch** turns round the upper margin of the Sylvian fissure, and is distributed to the ascending frontal convolution and to the posterior part of the middle frontal convolution.

(b^3) The **ascending parietal branch** emerges from the Sylvian fissure and passes upwards along the posterior border of the ascending parietal convolution, supplying that convolution and the superior parietal lobule.

(b^4) The **temporal branch** passes out of the Sylvian fissure, and turns downwards to supply the superior and middle temporal convolutions.

(b^5) The **parieto-temporal branch** continues backwards, in the direction of the main stem, and emerges from the posterior end of the Sylvian fissure ; it supplies the inferior parietal lobule, the external occipital convolutions, and the posterior part of the temporo-sphenoidal lobe.

Vertebral Artery.

The **vertebral artery** (a. vertebralis, Figs. 556 and 559) is the first branch given off from the subclavian trunk ; it arises from the upper and back part of the parent stem, opposite the interval between the anterior scalene and the longus colli muscles, and terminates at the lower border of the pons Varolii by uniting with its fellow of the opposite side to form the basilar artery.

Course and Relations.—The vertebral artery is divisible into four parts.

The **first part** runs upwards and backwards, between the scalenus anticus and the outer border of the longus colli, to the foramen in the transverse process of the sixth cervical vertebra. It is surrounded by a plexus of sympathetic nerve fibres, covered anteriorly by the vertebral and internal jugular veins, and crossed in front by the inferior thyroid artery. On the left side the terminal part of the thoracic duct also passes in front of it. The **second part** runs upwards through the foramina in the transverse processes of the upper six cervical vertebræ. As far as the second cervical vertebra its course is almost vertical; as it passes through the transverse process of the axis, however, it is directed obliquely upwards and outwards to the atlas. It is surrounded by a plexus of sympathetic nerve fibres, and also by a plexus of veins. The artery lies in front of the trunks of the cervical nerves, and internal to the intertransverse muscles. The **third part** emerges from the foramen in the transverse process of the atlas, between the anterior primary division of the suboccipital nerve internally and the rectus capitis lateralis externally, and runs almost horizontally backwards and inwards round the outer side and back of the superior articular process of the atlas. In this course it enters the suboccipital triangle, where it lies in the groove on the upper surface of the posterior arch of the atlas (sulcus arteriæ vertebralis). It is separated from the bone by the suboccipital nerve, and is overlapped superficially by the adjacent borders of the superior and inferior oblique muscles. Finally, this part of the artery passes beneath the oblique ligament of the atlas and enters the spinal canal.

The **fourth part** pierces the spinal dura mater and runs upwards into the cranial cavity. It passes between the roots of the hypoglossal nerve above and the first dentation of the ligamentum denticulatum below, pierces the arachnoid, and, gradually inclining inwards in front of the medulla, reaches the lower border of the pons Varolii, where it unites with its fellow of the opposite side to form the basilar artery.

Branches.—*From the first part.*—As a rule there are only a few small muscular twigs from this portion of the artery.

From the second part.—(1) **Muscular branches** which vary in number and size. They supply the deep muscles of the neck, and anastomose with the profunda cervicis, the ascending cervical, and the occipital arteries.

(2) **Spinal branches** (rami spinales) pass from the inner side of the second part of the vertebral artery through the intervertebral foramina into the spinal canal, where they give off twigs which pass along the roots of the spinal nerves to reinforce the anterior and

posterior spinal arteries; they supply the bodies of the vertebræ and the intervertebral discs, and they anastomose with corresponding arteries above and below.

From the third part.—(1) **Muscular branches** to the sub-occipital muscles.

(2) **Anastomotic branches** which unite with the princeps cervicis branch of the occipital and with the profunda cervicis artery.

From the fourth part.—(1) **Meningeal** (rami meningei).—One or two small branches given off before the vertebral artery pierces the dura mater. They ascend into the posterior fossa of the skull, where they anastomose with meningeal branches of the occipital and ascending pharyngeal arteries, and occasionally with branches of the middle meningeal artery.

(2) **Posterior Spinal** (a. spinalis posterior).—The posterior spinal branch springs from the vertebral directly after it has pierced the dura mater. It runs downwards upon the

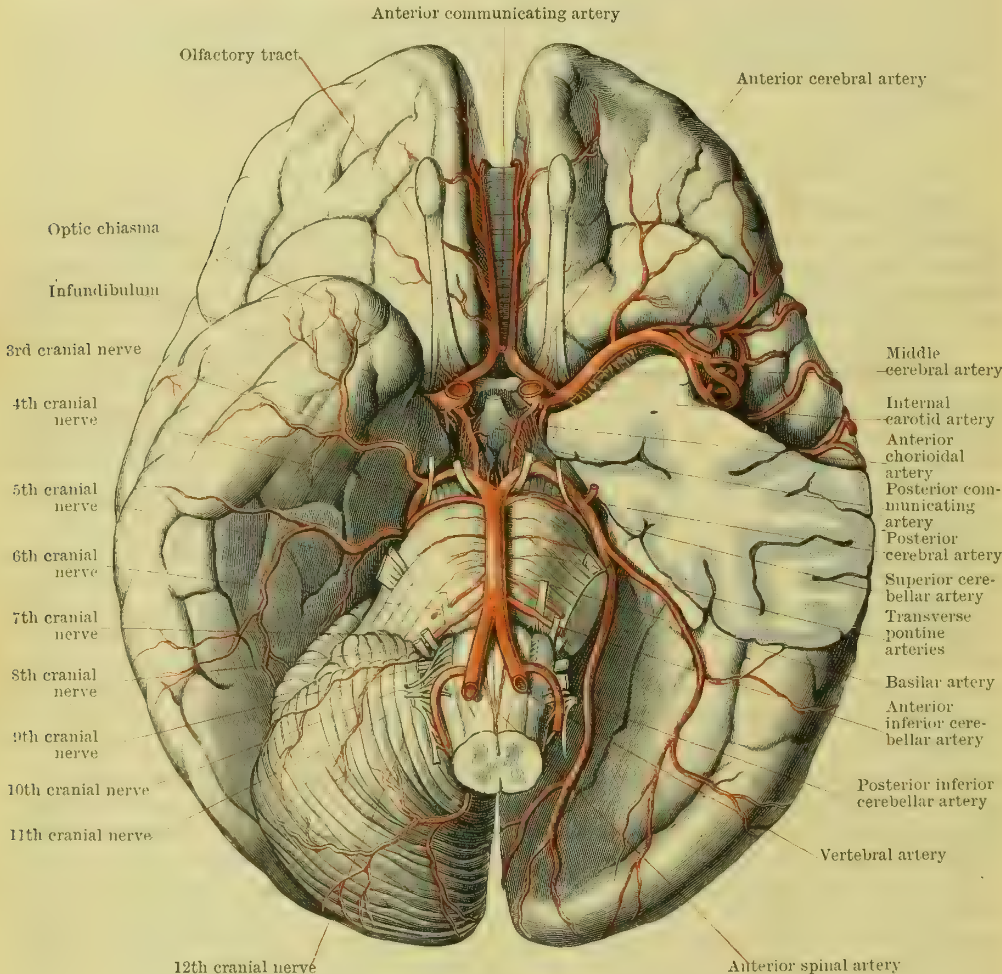


FIG. 559.—THE ARTERIES OF THE BASE OF THE BRAIN. THE CIRCLE OF WILLIS.

side of the medulla and the spinal cord in front of the posterior nerve roots. It is a slender artery, which is continued to the lower part of the cord by means of reinforcements from the spinal branches of the vertebral and intercostal arteries. It gives off branches to the pia mater, which form more or less regular anastomoses on the inner sides of the posterior nerve roots, and it terminates below by joining the anterior spinal artery.

(3) The **anterior spinal branch** (a. spinalis anterior) arises near the termination of the vertebral. It runs obliquely downwards and inwards, in front of the medulla, and unites with its fellow of the opposite side to form a single anterior spinal artery, which descends in front of the anterior fissure of the spinal cord, and is continued as a fine vessel along the filum terminale. The anterior spinal artery is reinforced as it descends by anastomos-

ing twigs from the spinal branches of the vertebral, intercostal, and lumbar arteries. It gives off branches which pierce the pia mater and supply the cord, and it unites below with the posterior spinal arteries.

(4) The **posterior inferior cerebellar** (a. cerebelli inferior posterior) is the largest branch of the vertebral artery. It arises a short distance below the pons and passes obliquely backwards round the medulla, at first between the roots of the hypoglossal nerve, and then between the roots of the spinal accessory and vagus nerves, into the vallecula of the cerebellum, where it divides into external and internal terminal branches.

The trunk of the artery gives branches to the medulla and to the chorioid plexus of the fourth ventricle. The internal terminal, or vermiform branch, runs backwards between the inferior vermiform process and the lateral lobe of the cerebellum; it supplies principally the former structure, and anastomoses with its fellow of the opposite side. The external or hemispheric branch passes outwards on the lower surface of the hemisphere and anastomoses with the superior cerebellar artery.

Basilar Artery (a. basilaris).—This artery is formed by the junction of the two vertebral arteries; it commences at the lower border and terminates at the upper border of the pons Varolii, bifurcating at its termination into the two posterior cerebral arteries.

Course and Relations.—It runs upwards in a shallow groove on the front of the pons Varolii, behind the sphenoidal section of the basi-cranial axis and between the sixth nerves.

Branches.—(1) The **transverse**, a series of small arteries which pass round the sides of the pons, supplying it (rami ad pontem), the middle peduncles of the cerebellum, and the roots of the fifth cranial nerve.

(2) The **auditory** (a. auditiva interna), a pair of long but slender branches which accompany the eighth cranial nerves. Each enters the corresponding internal auditory meatus with the seventh and eighth nerves, and, passing through the lamina cribrosa, is distributed to the internal ear.

(3) The **anterior inferior cerebellar** (a. cerebelli inferior anterior), two branches which arise, one on each side, from the middle of the basilar artery. They pass backwards on the lower surfaces of the lateral lobes of the cerebellum, and anastomose with the posterior inferior cerebellar branches of the vertebral arteries.

(4) The **superior cerebellar** (aa. cerebelli superiores) branches, two in number, arise near the termination of the basilar. Each passes outwards at the upper border of the pons, directly below the third nerve of the same side, and turning round the outer side of the crus cerebri below the fourth nerve, reaches the upper surface of the cerebellum, where it divides into an internal and an external branch. The internal branch supplies the upper surface of the vermiform process and the valve of Vieussens. The external branch is distributed over the upper surface of the lateral hemisphere, anastomosing at its margin with the inferior cerebellar arteries.

(5) **Posterior Cerebral Arteries** (aa. cerebri posteriores, Figs. 557 and 559).—These are the two terminal branches of the basilar. They run backwards and upwards, between the crura cerebri and the uncinate convolutions and parallel to the superior cerebellar arteries, from which they are separated by the third and fourth cranial nerves. Each posterior cerebral artery is connected with the internal carotid by the posterior communicating artery; it gives branches to the tentorial surface of the cerebrum, and is continued backwards, beneath the splenium of the corpus callosum, to the calcarine fissure, where it divides into calcarine and parieto-occipital branches, which pass to the outer surface of the occipital lobe and supply the inner and tentorial surfaces of the occipital lobe and the posterior part of its outer surface.

Branches.—(A) *Central or ganglionic.*—This group includes (a^1) A **postero-mesial** set of small vessels which pass on the inner side of the crus cerebri to the posterior perforated space. They supply the crus, the posterior part of the optic thalamus, the corpora albicantia, and the walls of the third ventricle.

(a^2) A **postero-lateral** set of small vessels which pass round the outer side of the crus cerebri. They supply the corpora quadrigemina, the brachia, the crus, the posterior part of the optic thalamus, and the corpora geniculata.

(a^3) A **posterior chorioidal** set of small branches which pass through the upper part of

the chorioidal fissure, and, after entering the posterior part of the velum interpositum, end in the chorioid plexus in the body of the lateral ventricle and the upper part of its descending cornu.

(B) *Cortical.*—(b^1) The **anterior temporal**, frequently a single branch of variable size, is not uncommonly replaced by several small branches. It supplies the anterior parts of the uncinate and the occipito-temporal convolutions.

(b^2) The **posterior temporal** is a larger branch than the anterior. It supplies the posterior part of the uncinate gyrus, the greater part of the occipito-temporal convolution, and the lingual lobule.

(b^3) The **calcarine branch** is the continuation of the posterior cerebral artery along the calcarine fissure. It supplies the cuneate lobe, the lingual lobule, and the posterior part of the outer surface of the occipital lobe.

(b^4) The **parieto-occipital branch**, smaller than the calcarine, passes along the corresponding fissure to the cuneus and precuneus.

Circle of Willis.—The cerebral arteries of opposite sides are intimately connected together at the base of the brain by anastomosing channels. Thus the two anterior cerebral arteries are connected with one another by the anterior communicating artery, whilst the two posterior cerebrals are in continuity through the basilar artery from which they rise. There is also a free anastomosis on each side between the carotid system of cerebral arteries and the vertebral system by means of the posterior communicating arteries, which connect the internal carotid trunks and posterior cerebral arteries.

The vessels referred to form the so-called **circle of Willis** (circulus arteriosus [Willisi]). This is situated at the base of the brain, in the region of the interpeduncular space, and encloses the following structures: the posterior perforated space, the corpora albicantia, the tuber cinereum, the infundibulum, and the optic commissure. The "circle" is irregularly polygonal in outline, and is formed posteriorly by the termination of the basilar and by the two posterior cerebral arteries, postero-laterally by the posterior communicating arteries and the internal carotids, antero-laterally by the anterior cerebral arteries, and in front by the anterior communicating artery.

It is stated that this free anastomosis equalises the flow of blood to the various parts of the cerebrum, and provides for the continuation of a regular blood-supply if one or more of the main trunks of the basal vessels should be obstructed.

ARTERIES OF THE UPPER EXTREMITY.

The main arterial stem of each upper extremity passes through the root of the neck, traverses the axillary space, and is continued through the upper arm to the forearm. In the latter it only runs a short distance, terminating just below the bend of the elbow by bifurcating into the radial and ulnar arteries which descend through the forearm to the hand. That portion of the common trunk which lies in the root of the neck is known as the **subclavian artery**, the part in the axillary space is termed the **axillary artery**, whilst the remaining part is called the **brachial artery.**

THE SUBCLAVIAN ARTERIES.

On the right side the subclavian artery (a. subclavia, Figs. 552 and 554) commences at the termination of the innominate artery behind the sterno-clavicular articulation, whilst that on the left side arises from the arch of the aorta behind the lower part of the manubrium sterni.

The right artery is about three inches long (75 mm.), and it lies in the root of the neck. The left artery is about four inches (100 mm.) long, and is situated not only in the root of the neck, but also in the superior mediastinal part of the thorax. In the root of the neck each artery arches outwards across the apex of the lung and behind the anterior scalene muscle, and is divided into three parts, which lie respectively to the inner side, behind, and to the outer side of the muscle. The extent to which the arch rises above the level of the clavicle varies considerably, and not uncommonly it reaches the level of the lower part of the thyroid body.

The first parts of the subclavian arteries differ materially from each other both in extent and relations. The relations of the second and third parts are similar on both sides.

The **first part of the left subclavian artery** springs from the arch of the aorta to the left of and behind the commencement of the left common carotid and on the left side of the trachea. It ascends, almost vertically, in the superior mediastinum to the root of the neck, where it arches upwards and outwards to the inner border of the scalenus anticus.

Relations.—*Posterior.*—In the superior mediastinum, from below upwards, it is in relation *behind* and with the left margin of the œsophagus, the thoracic duct, and the left longus colli muscle.

Anterior.—In front and to the right of the artery are the vagus, the left superior cardiac branch of the sympathetic, the left inferior cardiac branch of the vagus, the left phrenic nerve, and the left common carotid artery. It is also crossed obliquely by the left innominate vein above and by the left vagus nerve below, and it is overlapped on the left side by the left lung and pleura.

Lateral.—Internally it is in relation, from below upwards, with the trachea, the left recurrent laryngeal nerve, the œsophagus, and the thoracic duct.

Externally it is closely invested by the left pleura, and it ascends in a groove on the inner aspect of the left lung.

As it turns outwards at the root of the neck it lies behind the terminations of the internal jugular, vertebral, and subclavian veins, the phrenic nerve, the sterno-thyroid and sterno-hyoid muscles, the anterior jugular vein, and more superficially the sterno-mastoid muscle, and the deep cervical fascia; the thoracic duct arches obliquely over it, and it lies in front of the apex of the pleural sac.

The **first part of the right subclavian artery** (Fig. 552) extends from the back of the right sterno-clavicular articulation to the inner border of the scalenus anticus. It is thus limited to the root of the neck.

Relations.—*Posterior.*—Behind this part of the artery, and intervening between it and the upper two dorsal vertebræ, are the recurrent laryngeal nerve, the posterior part of the annulus Vieusseni, and the apex of the right pleural sac. *Anterior.*—In front it is in relation with the right vagus, the cardiac branches of the vagus and the sympathetic, the anterior portion of the annulus Vieusseni, the internal jugular and vertebral veins, and more superficially the sterno-hyoid and sterno-thyroid muscles, the anterior jugular vein, the sternal end of the clavicle, the sterno-clavicular ligaments, and the sterno-mastoid muscle. The recurrent laryngeal nerve passes *below* it and intervenes between it and the apex of the pleural sac.

The **second part of the subclavian artery**, on *each side*, extends from the inner to the outer border of the scalenus anticus, behind which it lies.

Relations.—*Behind* and *below* it is in relation with the pleural sac. In *front* it is covered by the anterior scalene and the sterno-mastoid muscles. The anterior scalene separates it from the subclavian vein, which also lies at a slightly lower level, from the transverse cervical and suprascapular arteries, from the anterior jugular vein, and, on the right side, from the phrenic nerve.

The **third part of the subclavian artery** is the most superficial portion. It extends from the outer border of the anterior scalene to the outer border of the first rib, lying partly in the clavicular portion of the posterior triangle and partly behind the clavicle and the subclavius muscle.

Relations.—It rests upon the upper surface of the first rib. Immediately *behind* it is the lowest trunk of the brachial plexus, which separates it from the middle scalene. In *front* of it and at a slightly lower level lies the subclavian vein. The external jugular vein crosses the inner part of this portion of the artery in its course to the subclavian vein, and just before its termination receives the transverse cervical and suprascapular veins; these vessels also pass superficial to the artery, which is thus covered by venous trunks; it is also crossed vertically, behind the veins, by the nerve to the subclavius muscle. The outer section of this part of the artery lies behind the clavicle and the subclavius muscle, and it is crossed from within outwards by the suprascapular artery,

which is separated from it by the layer of deep cervical fascia which binds the posterior belly of the omo-hyoid to the posterior border of the subclavian groove. More superficially the third part of the artery is covered by the superficial layer of the deep fascia, the descending clavicular branches of the cervical nerves, the platysma, and the skin.

Branches of the Subclavian Artery.

(1) The **vertebral artery** is distributed almost entirely to the head and neck, and its chief function is to supply the posterior part of the brain. Its description has therefore been given with that of the other cerebral arteries (see p. 773).

(2) **Thyroid Axis** (truncus thyreo-cervicalis, Figs. 552 and 554).—This branch arises close to the inner border of the scalenus anticus, and directly above the origin of the internal mammary artery, from the upper and front part of the subclavian artery. After a short upward course of about two lines (4 mm.), it ends under cover of the internal jugular vein by dividing into three branches—viz. the inferior thyroid, the transverse cervical, and the suprascapular.

(A) The **inferior thyroid artery** (a. thyreoidea inferior, Fig. 552) ascends along the anterior border of the scalenus anticus, and turns inwards opposite the cricoid cartilage to the middle of the posterior border of the lateral lobe of the thyroid body; it then curves inwards and downwards, and descends to the lower end of the lobe, where it divides into ascending and inferior terminal branches.

Relations.—*Behind* it is the vertebral artery externally and the longus colli muscle internally; the recurrent laryngeal nerve passes either in front of or behind the vessel, opposite the lower border of the thyroid body. It is covered *in front* by the carotid sheath, which contains the common carotid artery, the internal jugular vein, and the vagus nerve; the middle cervical ganglion of the sympathetic lies in front of the artery as it bends inwards, and on the left side the thoracic duct also passes in front of it.

Branches.—It gives off the following branches:—

(*a*) **Muscular.**—Numerous small branches pass to the scalenus anticus, the longus colli, the infra-hyoid muscles, and the inferior constrictor of the pharynx.

(*b*) The **ascending cervical branch** (a. cervicalis ascendens) usually springs from the inferior thyroid near its origin, though not uncommonly it rises separately from the thyroid axis. It ascends parallel with and internal to the phrenic nerve, in the angle between the rectus capitis anticus major and the scalenus anticus, to both of which it gives branches. It also gives off spinal branches which pass through the intervertebral foramina to the spinal canal, and it anastomoses with branches of the vertebral, occipital, ascending pharyngeal, and deep cervical arteries.

(*c*) **Œsophageal** (rami œsophagei) are small branches given to the walls of the œsophagus, which anastomose with the œsophageal branches of the thoracic aorta.

(*d*) **Tracheal branches** (rami tracheales) are distributed to the trachea; they anastomose with branches of the superior thyroid and with the bronchial arteries.

(*e*) An **inferior laryngeal branch** (a. laryngea inferior) accompanies the recurrent laryngeal nerve to the lower part of the larynx. It enters the larynx, beneath the lower border of the inferior constrictor, gives branches to its muscles and mucous membrane, and anastomoses with the laryngeal branch of the superior thyroid.

(*f*) The **ascending terminal branch** supplies the posterior and lower part of the thyroid body, and anastomoses with branches of the superior thyroid artery.

(*g*) The **inferior terminal branch** is distributed to the lower and inner part of the thyroid body. It anastomoses with its fellow of the opposite side and with branches of the superior thyroid artery.

(B) The **transverse cervical artery** (a. transversa colli, Figs. 552 and 554) runs upwards, outwards, and backwards from the thyroid axis across the posterior triangle of the neck to the anterior border of the trapezius, where it divides into superficial cervical (ramus ascendens) and posterior scapular (ramus descendens) branches. It is very variable in size, and not infrequently the posterior scapular arises separately from the third part of the subclavian.

Immediately after its origin, under cover of the internal jugular vein, it crosses the scalenus anticus, lying superficial to the phrenic nerve and under cover of the sterno-mastoid muscle; on the left side it is also crossed superficially by the terminal part of the thoracic duct. Passing from beneath the sterno-mastoid, it enters the

lower part of the posterior triangle of the neck, where it lies upon the trunks of the brachial plexus, and, as it runs upwards and backwards to its termination, it passes beneath the posterior belly of the omo-hyoid.

Branches.—(*a*) Small **muscular branches** to the surrounding muscles.

(*b*) The **superficial cervical artery** (a. cervicalis superficialis), usually a slender branch, passes beneath the trapezius; it runs upwards over the levator anguli scapulæ

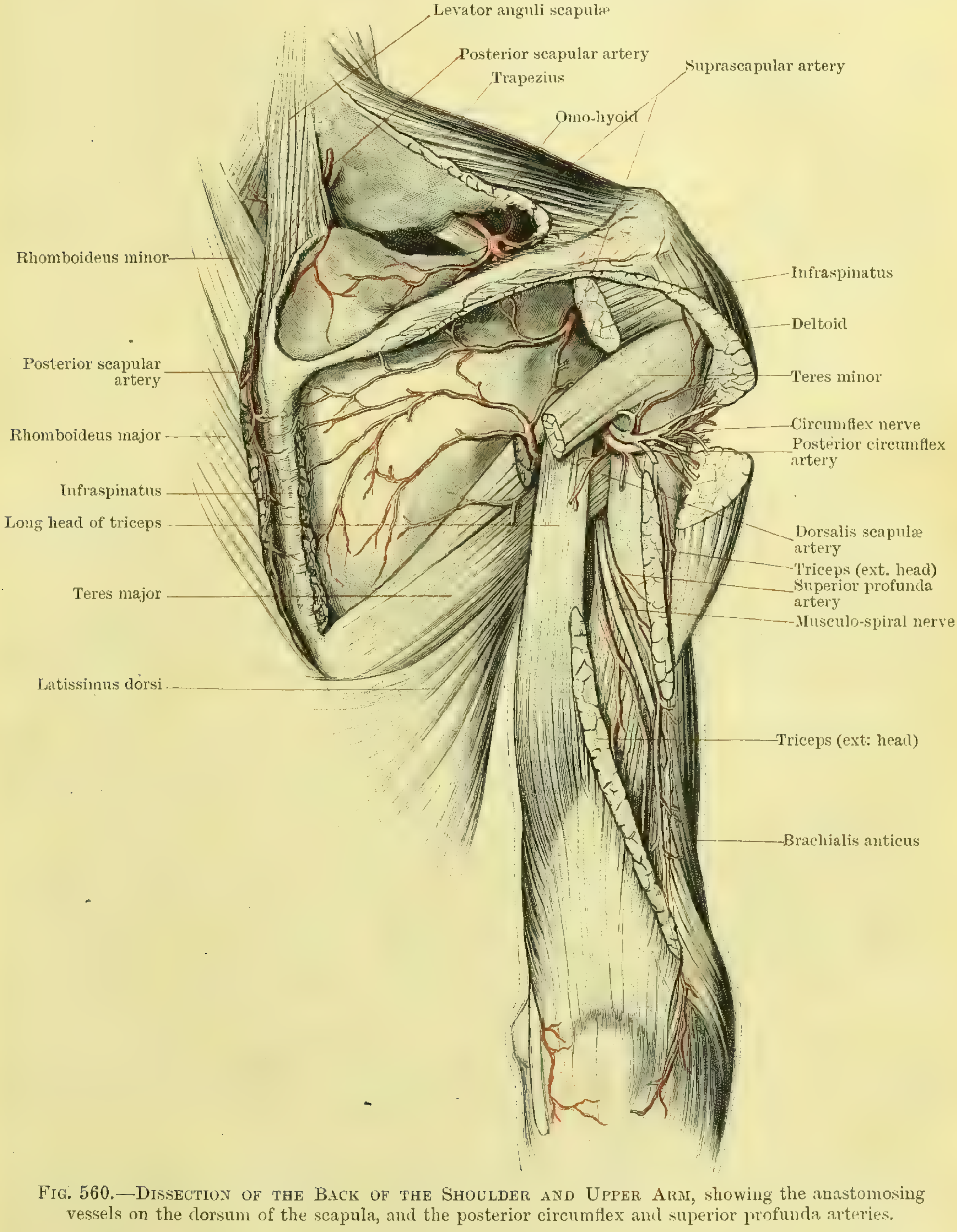


FIG. 560.—DISSECTION OF THE BACK OF THE SHOULDER AND UPPER ARM, showing the anastomosing vessels on the dorsum of the scapula, and the posterior circumflex and superior profunda arteries.

and upon the splenius, and anastomoses with the arteria princeps cervicis, a branch of the occipital artery, and it sends branches downwards which accompany the spinal accessory nerve and anastomose with the posterior scapular and suprascapular arteries.

(*c*) The **posterior scapular artery** descends beneath the levator anguli scapulæ and the rhomboid muscles, close to the posterior border of the scapula. It runs parallel with, and a short distance away from, the nerve to the rhomboid muscles, and it sends branches into the supraspinous, the infraspinous, and the subscapular fossæ, which

anastomose with branches of the suprascapular and subscapular arteries. It also sends branches backwards through and between the rhomboid muscles, which anastomose with the superficial cervical artery and with the dorsal branches of the intercostal arteries.

(C) The **suprascapular artery** (a. transversa scapulæ) springs from the thyroid axis, and terminates in the infraspinous fossa of the scapula. As a rule it is smaller than the transverse cervical artery.

Commencing behind the internal jugular vein, it crosses the scalenus anticus and phrenic nerve, and is covered in front by the sterno-mastoid and the anterior jugular vein; on the left side it lies behind the termination of the thoracic duct also. Continuing outwards and backwards behind the clavicle, and crossing superficially to the third part of the subclavian artery and the cords of the brachial plexus, it reaches the suprascapular notch and passes over the suprascapular ligament. From this point it descends with the suprascapular nerve through the supraspinous fossa and beneath the supraspinatus muscle, and passing through the great scapular notch under the spino-glenoid ligament, enters the infraspinous fossa, where it anastomoses with the dorsal branch of the subscapular and with branches of the posterior scapular arteries.

Branches.—(*a*) **Muscular**, to the sterno-mastoid, the subclavius, and the muscles on the dorsum of the scapula.

(*b*) The **medullary**, a small branch to the clavicle.

(*c*) The **suprasternal**, to the sternal end of the clavicle and the sterno-clavicular joint.

(*d*) **Acromial branches**, which ramify over the acromion process, anastomosing with the acromial branches of the acromio-thoracic and the posterior circumflex arteries.

(*e*) **Articular**, to the acromio-clavicular and shoulder joints.

(*f*) The **subscapular**, which is given off as the artery, passes over the transverse suprascapular ligament. It passes down into the subscapular fossa, gives branches to the subscapularis, and anastomoses with the branches of the subscapular and posterior scapular arteries.

(*g*) **Supraspinous**, which ramify in the supraspinous fossa, supplying the muscle, and anastomosing with the posterior scapular.

(*h*) **Terminal branches** ramify in the infraspinous fossa, and anastomose with the dorsalis scapulæ and with branches of the posterior scapular artery.

(3) **Internal Mammary Artery** (a. mammaria interna, Fig. 552).—This arises from the lower and front part of the subclavian at the inner border of the scalenus anticus and immediately below the origin of the thyroid axis. It terminates behind the inner extremity of the sixth intercostal space by dividing into the musculo-phrenic and the superior epigastric arteries.

The artery passes at first downwards, forwards, and inwards, lying upon the pleura, and behind the subclavian vein, the sternal end of the clavicle, and the cartilage of the first rib: it is crossed obliquely from without inwards by the phrenic nerve, which usually passes in front of it. From the cartilage of the first rib it descends vertically, about half-an-inch from the border of the sternum, and lies in the upper part of its course upon the pleura, and in the lower part upon the triangularis sterni. It is covered in front by the cartilages of the upper six ribs, the intervening intercostal muscles, and the terminal portions of the intercostal nerves, and it is accompanied by two vena comites, which unite together above and on its inner side to form a single trunk which terminates in the innominate vein.

Branches.—(*a*) The **comes nervi phrenici** (a. pericardiaco-phrenica), or superior phrenic artery, is a long slender branch which is given off from the upper part of the internal mammary. It accompanies the phrenic nerve through the superior and middle mediastinal spaces to the diaphragm, where it anastomoses with the inferior phrenic and musculo-phrenic arteries. In its course downwards the artery gives off numerous small branches to the pleura and pericardium, which anastomose with offsets of the mediastinal and pericardial branches of the aorta and internal mammary arteries, and also with the bronchial arteries, forming the wide-meshed subpleural plexus of Turner.

(*b*) **Mediastinal branches** (aa. mediastinales anteriores), small and numerous, pass to the areolar tissue of the anterior mediastinal space and supply the remains of the thymus gland and the sternum.

(*c*) **Pericardial.**—These are several small branches which ramify on the anterior aspect of the pericardium.

(*d*) The **anterior intercostal** (rami intercostales), are two in number in each of the upper six intercostal spaces. They pass outwards for a short distance either between the pleura or the triangularis sterni and the internal intercostal muscles; they then pierce the internal intercostal muscles, and ramify between them and the external intercostal muscles, anastomosing with the aortic and superior intercostal arteries and their collateral branches.

(*e*) The **anterior perforating branches** (rami perforantes), one in each of the upper six intercostal spaces, are small vessels which pass forwards with the intercostal nerves, piercing the internal intercostal muscle, the anterior intercostal membrane, and the pectoralis major, to terminate in the skin and subcutaneous tissue. They supply twigs to the sternum, and those in the third and fourth spaces, usually the largest of the series, give off branches to the mammary gland.

(*f*) The **musculo-phrenic** (a. musculo-phrenica), or external terminal branch of the internal mammary artery, runs downwards and outwards from the sixth intercostal space to the tenth costal cartilage. In the upper part of its course it lies upon the thoracic surface of the diaphragm, but it pierces the muscle about the level of the eighth costal cartilage, and terminates on its abdominal surface. Its branches are :—

(i.) **Muscular**, which supply the diaphragm and anastomose with the superior and inferior phrenic arteries.

(ii.) **Anterior intercostal branches**, two in each of the seventh, eighth, and ninth intercostal spaces; they are distributed in the same manner as the corresponding branches of the internal mammary artery, and terminate by anastomosing with the aortic intercostals and their collateral branches.

(*g*) The **superior epigastric** (a. epigastrica superior), or internal terminal branch of the internal mammary artery, descends into the anterior wall of the abdomen. It leaves the thorax, between the sternal and costal origins of the diaphragm, and enters the sheath of the rectus, lying first behind, and then in the substance of the rectus muscle. It terminates by anastomosing with branches of the deep epigastric artery. Its branches are :—

(i.) **Muscular**, to the rectus, to the flat muscles of the abdominal wall, and to the diaphragm.

(ii.) **Anterior Cutaneous.**—These branches pierce the rectus and the anterior portion of its sheath. They accompany the anterior terminal branches of the lower six intercostal nerves, and terminate in the subcutaneous tissues and skin of the middle portion of the anterior abdominal wall.

(iii.) **Ensiform**, a small branch which crosses the front of the ensiform process to anastomose with its fellow of the opposite side. It supplies the adjacent muscles and skin.

(iv.) **Hepatic branches** of small size pass backwards in the falciform ligament to the liver, where they anastomose with branches of the hepatic artery.

(4) **Superior Intercostal Artery** (truncus costo-cervicalis, Fig. 556).—The superior intercostal artery springs from the back of the second part of the subclavian artery on the right side and from the first part on the left side. It runs upwards and backwards from its origin, over the apex of the pleural sac, to the neck of the first rib in front of which it descends, between the first thoracic ganglion of the sympathetic cord and the first dorsal nerve, to the first intercostal space, where it divides into two branches which are distributed to the upper two intercostal spaces.

Branches.—(*a*) The **profunda cervicis** (a. cervicalis profunda).—This branch sometimes arises from the subclavian artery directly; but more commonly it springs from the superior intercostal at the upper border of the neck of the first rib. It runs backwards, like the dorsal branch of an intercostal artery, passes between the first dorsal and last cervical nerves, and between the transverse process of the last cervical vertebra and the neck of the first rib to the back of the neck, where it ascends between the complexus and the semispinalis colli muscle to terminate by anastomosing with the deep branch of the princeps cervicis artery. It also anastomoses with branches of the ascending cervical and vertebral arteries, supplies the adjacent muscles, and sends a spinal branch through the intervertebral foramen between the last cervical and the first dorsal vertebræ into the spinal canal, which anastomoses with the spinal branches of the vertebral and intercostal arteries.

(*b*) **Terminal.**—The two terminal branches run outwards, one in the first and one in the second intercostal space. Each runs near the upper border of its space, passing at first between the pleura and the posterior intercostal membrane, and then between the

internal and external intercostal muscles. The branches terminate by anastomosing with anterior intercostal branches of the internal mammary artery. Each gives off muscular branches to the intercostal muscles, a nutrient branch to the rib below which it lies, and a collateral branch which runs along the lower border of the space and terminates by anastomosing with an anterior intercostal branch of the internal mammary artery.

THE AXILLARY ARTERY.

The **axillary artery** (a. axillaris) lies in the axillary space. It is the direct continuation of the subclavian artery, and it becomes the brachial artery.

The axillary artery commences at the outer border of the first rib, at the apex of the axillary space. It descends, with an outward inclination, along the external

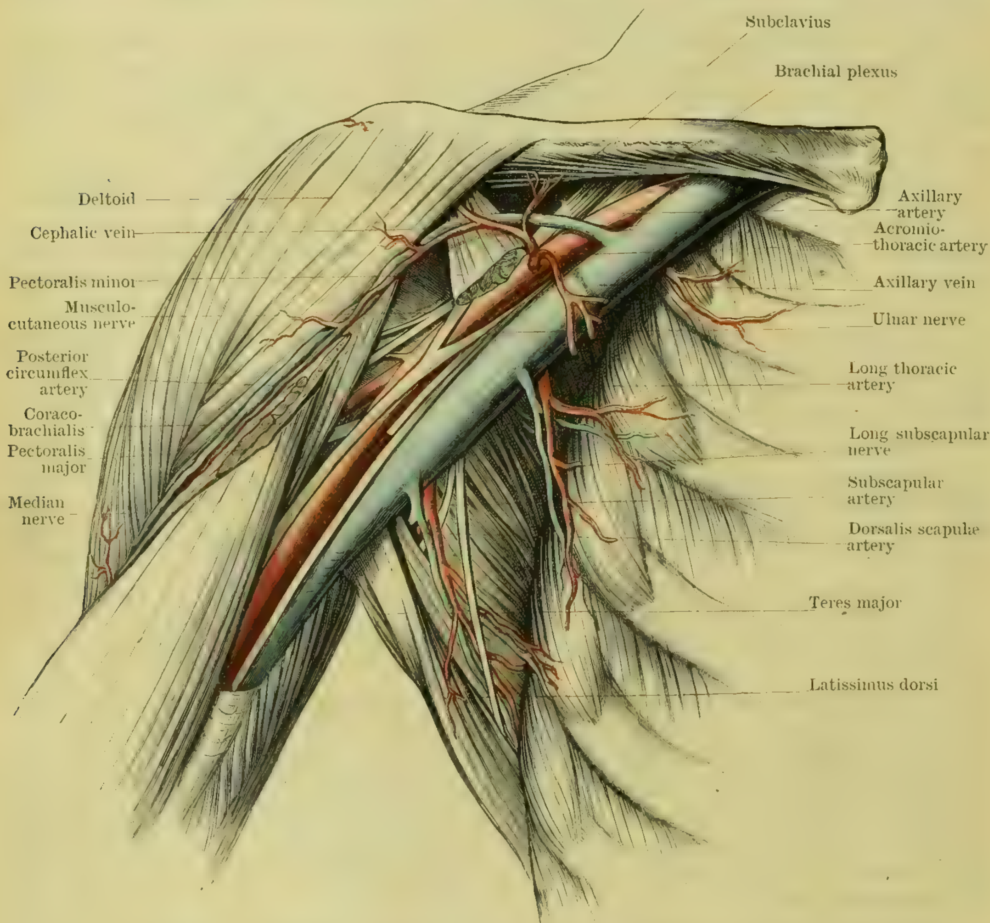


FIG. 561.—THE AXILLARY ARTERY AND ITS BRANCHES AND RELATIONS.

wall of the space, *i.e.* to the inner side of the shoulder-joint and the humerus, to the lower border of the teres major, where it becomes the brachial artery. A line drawn from the middle of the clavicle to the inner border of the prominence of the coraco-brachialis and biceps muscles, when the arm is abducted until it is at right angles with the side, indicates the position and direction of the artery.

The position and direction, however, and to a certain extent the relations also of the axillary artery, are modified by changes in the position of the upper extremity. With the arm hanging by the side the axillary artery describes a curve with the concavity directed downwards and inwards, and the vein is to its inner side. When the arm is at right angles with the side, the axillary artery is almost straight, it lies closer to the outer wall of the axilla, and the vein overlaps it in front and on the inner side. When the arm is raised above the level of the

shoulder the axillary artery is curved over the head of the humerus, and the vein lies still more in front of it.

For descriptive purposes the artery is divided into three parts; the first part lies above, the second behind, and the third part below the pectoralis minor muscle.

Though we have followed the usual custom in describing three parts of the axillary artery, a division which is perhaps of practical interest in so far as it emphasises the fact that the axillary artery is surgically accessible above the pectoralis minor, it is to be noted that the upper border of the pectoralis minor is usually exactly opposite the outer border of the first rib, at the point where the axillary artery begins. In the strict sense, therefore, no part of the artery is above the pectoralis minor.

Relations of the first part.—*Posterior.*—The first part of the artery is enclosed, together with the vein and the cords of the brachial plexus, in a prolongation of the cervical fascia known as the axillary sheath, behind which is the upper serration of the serratus magnus muscle, the contents of the first intercostal space, the internal anterior thoracic and the posterior thoracic nerves, the latter descending vertically between the artery and the serratus magnus. *Anterior.*—It is covered in front by the costo-coracoid membrane, the upper part of which splits to enclose the subclavius muscle. The membrane intervenes between the artery and the cephalic vein, the branches of the external anterior thoracic nerve, the branches of the acromio-thoracic artery with their accompanying veins, and the clavicular part of the pectoralis major muscle, superficial to which are the deep fascia, the platysma, the descending clavicular branches of the cervical plexus, and the superficial fascia and the skin. Behind the costo-coracoid membrane the artery is crossed by a loop of communication between the external and internal anterior thoracic nerves. *Lateral.*—Above and to the outer side are the cords of the brachial plexus and the external anterior thoracic nerve. Below and to the inner side is the axillary vein, the internal anterior thoracic nerve intervening.

Relations of the second part.—*Posterior.*—Behind this portion of the artery is the posterior cord of the brachial plexus and a layer of fascia which separates it from the subscapularis muscle. *Anterior.*—In front is the pectoralis minor, and more superficially the pectoralis major, the fasciæ and skin. *Lateral.*—To the outer side lies the outer cord of the brachial plexus. On the inner side the inner cord of the plexus lies in close relation to the artery, and intervenes between it and the axillary vein.

Relations of the third part.—*Posterior.*—The third part of the artery rests posteriorly upon the lower border of the subscapularis, the latissimus dorsi, and the teres major. It is separated from the fibres of the subscapularis by the circumflex and musculo-spiral nerves, and from the latissimus dorsi and teres major by the musculo-spiral nerve alone. *Anterior.*—It is crossed in front by the inner head of the median nerve. In its upper half it lies under cover of the lower part of the pectoralis major, the fascia and skin, whilst its lower part, which is superficial, is covered by skin and fascia only. *Lateral.*—To the outer side lie the median and musculo-cutaneous nerves and the coraco-brachialis muscle. To the inner side is the axillary vein. The two vessels are, however, separated by two of the chief branches of the inner cord of the brachial plexus. In the angle between the vein and the artery, and somewhat in front of the latter, lies the internal cutaneous nerve; in the angle behind is the ulnar nerve. The lesser internal cutaneous nerve lies internal to the vein, and the venæ comites of the brachial artery ascend along the inner side, to terminate in the axillary vein at the lower border of the subscapularis muscle.

Branches of the Axillary Artery.

(1) The **superior thoracic** (a. thoracalis suprema, Fig. 561), a small branch which arises from the first part of the axillary at the lower border of the subclavius. It runs downwards and inwards across the first intercostal space, pierces the inner part of the costo-coracoid membrane, and supplies branches to the subclavius, the pectoralis major and minor, and to the serratus magnus and the intercostal muscles; it anastomoses with branches of the suprascapular, the internal mammary, and the acromio-thoracic arteries.

(2) The **acromio-thoracic** (a. thoraco-acromialis, Fig. 561) arises near the upper border of the pectoralis minor, from the second part of the axillary artery. It is a

very short trunk, of considerable size, which passes forwards, pierces the costo-coracoid membrane, and terminates beneath the clavicular portion of the pectoralis major by dividing into four terminal branches—clavicular, pectoral, humeral, and acromial.

(*a*) The **clavicular branch** (ramus clavicularis) is a long slender artery which runs upwards and inwards to the sterno-clavicular joint, anastomosing with the superior thoracic, with branches of the suprascapular, and with the first perforating branch of the internal mammary artery. It supplies the adjacent muscles and the sterno-clavicular articulation.

(*b*) The **pectoral** (ramus pectoralis), or thoracic, is a large branch which descends between the two pectoral muscles, to both of which it gives branches, and anastomoses with the intercostal and long thoracic arteries.

(*c*) The **humeral branch** (ramus deltoideus) runs outwards to the groove between the pectoralis major and the deltoid, in which it descends in company with the cephalic vein to the insertion of the deltoid. It anastomoses with the acromial branch and with the anterior circumflex artery, and it gives branches to the pectoralis major and deltoid muscles and to the skin.

(*d*) The **acromial branch** (ramus acromialis) runs upwards and outwards across the tip of the coracoid process to the acromion, where it anastomoses with the last-described branch, with the acromial branches of the suprascapular, and with the posterior circumflex arteries. It gives branches to the deltoid.

(3) The **long thoracic** (a. thoracalis lateralis) arises from the second part of the axillary, and descends along the lower border of the pectoralis minor to anastomose with the intercostal and subscapular arteries, and with the pectoral branch of the acromio-thoracic. It supplies the adjacent muscles, and sends branches to the outer part of the mammary gland, hence it is not infrequently called the **external mammary artery**.

(4) The **alar thoracic** is only occasionally present as a distinct branch, but it is frequently represented by a number of small irregular branches, which may either arise from the axillary or from the thoracic and subscapular branches. It is distributed to the glands and areolar tissue in the axilla.

(5) The **subscapular artery** (a. subscapularis) is the largest branch of the axillary artery. It arises from the third part of the artery, opposite the lower border of the subscapularis, along which it descends to the lower angle of the scapula and to the inner wall of the axillary space. It is accompanied by the second or long subscapular nerve; it supplies the adjacent muscles, and it anastomoses with the posterior scapular, the suprascapular, the long thoracic, and the lateral branches of the intercostal arteries, and gives off one named branch, the dorsalis scapulæ.

The **dorsalis scapulæ artery** (a. circumflexa scapulæ) is frequently larger than the continuation of the subscapular artery. It arises about one and a half inches (37 mm.) from the commencement of the subscapular trunk, and passes backwards into the triangular space between the subscapularis above, the teres major below, and the long head of the triceps externally. Turning round, and usually grooving the axillary border of the scapula, under cover of the teres minor, it enters the infraspinous fossa, where it breaks up into branches which anastomose with branches of the posterior scapular and suprascapular arteries. Whilst it is in the triangular space the dorsal artery gives off an *infrascapular branch* which passes into the subscapular fossa beneath the subscapularis, and terminates by anastomosing with the branches of the posterior and suprascapular arteries. It also gives off in the same situation a descending branch, which runs downwards to the lower angle of the scapula between the teres major and minor muscles, and small branches are given to the deltoid and scapular head of triceps.

(6) The **posterior circumflex** (a. circumflexa humeri posterior) arises from the third part of the axillary artery and passes backwards, accompanied by the circumflex nerve, through the quadrilateral space, which is bounded by the teres minor above, the teres major below, the long head of the triceps internally, and the humerus externally. It turns round the surgical neck of the humerus under cover of the deltoid muscle, and terminates in numerous branches which

supply the deltoid. As a rule it is an artery of large size, only slightly smaller than the subscapular.

Branches.—(*a*) **Muscular** to the teres major and minor, the triceps heads, long and external, and the deltoid; (*b*) An **acromial branch**, which ascends to the acromial process, where it anastomoses with the acromial branches of the suprascapular and the acromio-thoracic arteries; (*c*) A **descending branch**, which runs downwards along the external head of the triceps to anastomose with the superior profunda artery; (*d*) **Articular** to the shoulder-joint; (*e*) **Nutrient** to the head of the humerus; (*f*) **Terminal**, which supply a large portion of the deltoid, and anastomose with the anterior circumflex and acromio-thoracic arteries.

(7) The **anterior circumflex artery** (a. circumflexa humeri anterior) is a small branch which is given off from the third part of the axillary close to, or in common with, the posterior circumflex. It passes outwards beneath the coraco-brachialis and the two heads of the biceps, round the front of the surgical neck of the humerus, and terminates by anastomosing with the posterior circumflex. At the bicipital groove it gives a well-marked ascending bicipital branch which ascends along the long head of the biceps, supplying the sheath of the tendon, and giving branches to the shoulder-joint. It also gives muscular branches to the adjacent muscles, one of which descends along the tendon of insertion of the pectoralis major.

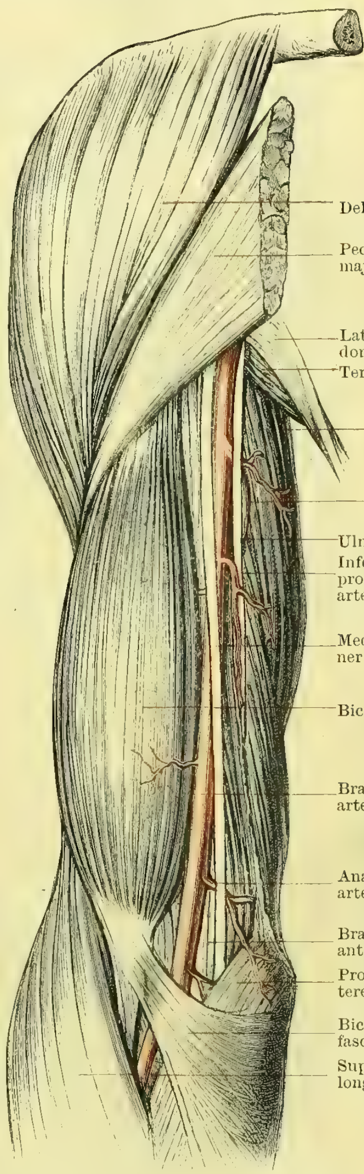


Fig. 562.—The Brachial Artery and its Branches.

THE BRACHIAL ARTERY.

The **brachial artery** (a. brachialis) is the direct continuation of the axillary. It commences at the lower border of the teres major, and terminates in the ante-cubital fossa at the level of the neck of the radius, by dividing into the radial and ulnar arteries.

The general course of the brachial artery is downwards and outwards, along the inner side of the arm. Its position may be indicated on the surface by a line drawn from the lower part of the axillary space at the junction of its anterior and middle thirds to the centre of the bend of the elbow.

Relations.—*Posterior.*—It rests successively upon the long head of the triceps, the musculo-spiral nerve and the superior profunda artery intervening, the internal head of the triceps, the insertion of the coraco-brachialis and the brachialis anticus. *Anterior.*—It is overlapped *in front* by the inner border of the biceps, is crossed at its centre by the median nerve, and in addition is covered by deep and superficial fascia and by skin. In the ante-cubital fossa a thickened portion of the deep fascia, the semilunar or bicipital fascia, separates it from the median basilic vein and the anterior branch of the internal cutaneous nerve, both of which lie in the superficial fascia. *Lateral.*—To the *outer side* it is in relation above with the median nerve, and below with the biceps. To the *inner side* it is in relation in the upper part of its extent with the basilic vein, the internal

cutaneous, lesser internal cutaneous, and ulnar nerves, and in the lower part with the median nerve. Two venæ comites, one on each side, accompany the artery, and communications between these pass across the vessel.

Branches of the Brachial Artery.

(1) The **superior profunda** (a. profunda brachii) is a large branch which arises from the inner and back part of the brachial soon after its commencement. It runs downwards and outwards, with the musculo-spiral nerve, in the musculo-spiral groove, and divides at the back of the humerus into two terminal branches, the anterior and the posterior. Not infrequently this division takes place at a higher level, and the artery appears double. The anterior terminal branch accompanies the musculo-spiral nerve through the external intermuscular septum, and descends between the supinator longus and the brachialis anticus to the front of the external condyle, where it anastomoses with the radial recurrent artery. The posterior terminal branch descends behind the external intermuscular septum, and anastomoses behind the external condyle with the posterior interosseous recurrent artery and with the anastomotic artery.

Whilst they are lying at the back of the humerus one of the terminal branches gives off—(*a*) a slender twig, which descends in the substance of the internal head of the triceps to the back of the elbow, where it anastomoses with the anastomotic artery; (*b*) a nutrient branch, which enters a foramen on the posterior surface of the humerus; and (*c*) an ascending branch, which anastomoses with the descending branch of the posterior circumflex artery.

(2) **Muscular branches** are given to the biceps, coraco-brachialis, brachialis anticus, triceps, and pronator radii teres.

(3) **Nutrient.**—A small artery which arises from the middle of the brachial and enters the nutrient foramen on the inner side of the shaft of the humerus.

(4) The **inferior profunda** (a. collateralis ulnaris superior) is smaller than the superior profunda, with which it sometimes rises by a common trunk; usually, however, it springs from the inner and back part of the middle of the brachial. It runs downwards and backwards, with the ulnar nerve, through the internal intermuscular septum, and then, descending more vertically, reaches the back of the internal condyle of the humerus, where it terminates by anastomosing with the posterior ulnar recurrent and anastomotic arteries.

(5) The **anastomotic** (a. collateralis ulnaris inferior) rises from the inner side of the brachial artery about two inches (50 mm.) above its termination. It runs inwards behind the median nerve and in front of the brachialis anticus, it then pierces the internal intermuscular septum, and turns outwards between the inner head of the triceps and the posterior surface of the bone to the external condyle. It supplies the adjacent muscles and anastomoses, in front of the internal condyle, with the anterior ulnar recurrent, behind the internal condyle with the posterior ulnar recurrent and the inferior profunda, at the middle of the back of the humerus with a branch of the superior profunda, and behind the external condyle with the posterior terminal branch of the superior profunda and the posterior interosseous recurrent artery.

The Radial Artery.

The **radial artery** (a. radialis, Figs. 563, 564, and 565) is the smaller of the two terminal branches of the brachial artery but it is the more direct continuation of the parent trunk. It commences in the ante-cubital fossa opposite the neck of the radius, and terminates in the palm of the hand, by anastomosing with the deep branch of the ulnar artery, and thus completing the deep palmar arch.

The trunk is divisible into **three parts.**

The *first part* lies on the front of the forearm. It runs downwards and somewhat outwards to the apex of the styloid process of the radius. The *second part* curves round the outer side of the wrist and across the back of the trapezium to reach the proximal end of the first interosseous space. The *third part* passes

forwards through the first interosseous space to the palm of the hand, where it joins the deep branch of the ulnar artery.

Relations of the first part.—*Posterior.*—It passes successively in front of the following structures: the tendon of insertion of the biceps, the supinator brevis, the pronator radii teres, the radial portion of the flexor sublimis digitorum, the flexor longus pollicis, the pronator quadratus, and the anterior ligament of the wrist-joint. *Anterior.*—The artery is overlapped in the upper half by the anterior border of the supinator longus; in the remainder of its extent it is covered only by skin and fascia. *Lateral.*—To the *outer side* is the supinator longus and the radial nerve. This latter lies quite near to the artery in its middle third. To the *inner side* is the pronator radii teres above and the flexor carpi radialis below. Two vena comites, one on each side, accompany the artery.

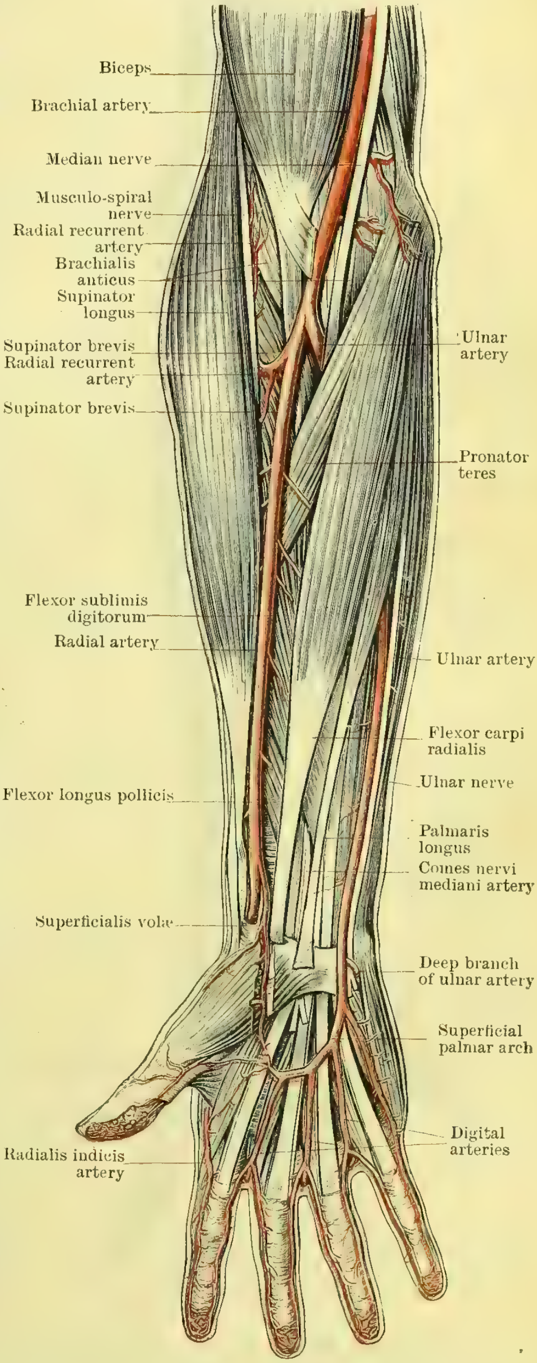


Fig. 563.—Superficial Dissection of the Front of the Forearm and Hand, showing the radial and ulnar arteries and the superficial palmar arch with its branches.

Branches of the first part.—(1) The **radial recurrent** (a. recurrens radialis) arises in the ante-cubital fossa. It springs from the outer side of the radial in front of the supinator brevis. It runs outwards, passes between the radial and posterior interosseous nerves, and then ascends to the external condyle of the humerus, where it anastomoses with the anterior terminal branch of the superior profunda. The radial recurrent supplies numerous muscular branches to the supinator longus, the supinator brevis, the extensor carpi radialis longior, and the extensor carpi radialis brevior.

(2) **Muscular branches** (rami musculares) to the muscles on the radial side of the anterior aspect of the forearm.

(3) The **superficialis volæ** (ramus volaris superficialis, Fig. 563) is a slender vessel which arises a short distance above the wrist and runs downwards across the ball of the thumb. It usually pierces the superficial muscles of the thenar eminence, and terminates either in their substance or by uniting with the ulnar artery and completing the superficial palmar arch of the hand.

(4) An **anterior radial carpal branch** (ramus carpeus volaris) passes inwards beneath the flexor tendons and their synovial sheaths, and crosses the anterior carpal ligaments. It anastomoses with the anterior carpal branch of the ulnar artery to form the anterior carpal arch, and it receives communications from the anterior interosseous artery and from the deep palmar arch.

Relations of the second part.—As it curves round the outer side and the back of the wrist, the radial artery lies upon the external lateral ligament of the intercarpal joint and upon the back of the trapezium. It is crossed by the extensor ossis metacarpi pollicis, the extensor brevis pollicis, and the extensor longus pollicis; more superficially it is covered by fascia, in which are some filaments of the radial nerve and the commencement of the radial vein, and by skin.

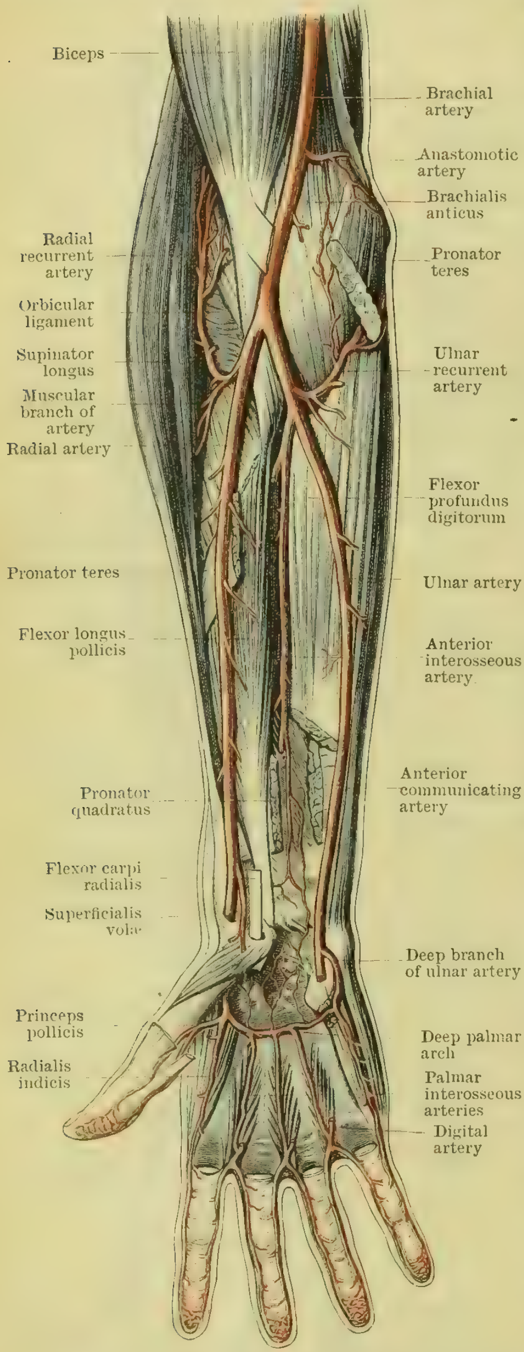


FIG. 564.—DEEP DISSECTION OF THE FRONT OF THE FOREARM AND HAND, showing the radial and ulnar arteries and their branches and the deep palmar arch and its branches.

Branches of the second part.—(1) **Dorsales Pollicis.**—Two small arteries which run along the borders of the dorsal aspect of the thumb; they supply the skin, tendons, and joints, and anastomose with the palmar digital arteries.

(2) **Dorsalis Indicis.**—A slender artery which runs downwards on the ulnar head of the first dorsal interosseous muscle and along the dorsal aspect of the radial border of the index-finger.

(3) and (4) The **metacarpal** or **first dorsal interosseous** and **posterior radial carpal** arise by a common trunk which crosses beneath the extensor longus pollicis.

(*a*) The metacarpal branch (a. metacarpea dorsalis) descends on the dorsal aspect of the second dorsal interosseous muscle, and divides opposite the heads of the metacarpal bones into two digital branches which supply the adjacent sides of the index and middle fingers. (*b*) The posterior carpal branch (ramus carpeus dorsalis) runs inwards on the dorsal carpal ligaments, and beneath the extensor tendons, to anastomose with the posterior carpal branch of the ulnar artery, and to complete the **dorsal carpal arch** which receives the terminations of the anterior and posterior interosseous arteries. The dorsal carpal arch gives off the **second** and **third dorsal interosseous arteries** (aa. metacarpæ dorsales), which descend on the dorsal aspects of the third and fourth dorsal interosseous muscles as far as the heads of the metacarpal bones, where each divides into two branches (aa. digitales dorsales), for the adjacent sides of the third and fourth and the fourth and fifth fingers respectively.

Each dorsal interosseous artery is connected with the deep palmar arch by a **superior perforating branch** which passes through the upper part of the corresponding interosseous space, and with a digital branch from the superficial palmar arch by an **inferior perforating branch** which passes through the lower part of the space.

Relations of the third part.—The third part of the radial artery passes forwards between the two heads of the first dorsal interosseous muscle to reach the palm, where it turns inwards beneath the upper part of the oblique adductor muscle of the thumb, and, after passing through the upper fibres of the transverse adductor, or between the adjacent borders of the oblique and transverse adductors, unites with the deep branch of the ulnar artery, completing the deep palmar arch.

Branches of the third part.—(1) The **princeps pollicis** (a. princeps pollicis) branch is given off as soon as the radial artery enters the palm. It runs downwards in front of the first metacarpal bone, between the oblique adductor and the opponens pollicis, and under cover of the long flexor tendon, and divides near the lower end of the bone into collateral branches which run along the sides of the thumb and anastomose with the dorsales pollicis arteries.

(2) The **radialis indicis** (a. volaris indicis radialis) is a branch which descends between the ulnar head of the first dorsal interosseous muscle and the transverse adductor of the thumb, and runs along the radial side of the index-finger to its tip, supplying the adjacent tissues; not uncommonly it anastomoses with the superficial palmar arch.

The Ulnar Artery.

The **ulnar artery** (a. ulnaris, Figs. 563 and 564) is the larger terminal branch, but the less direct continuation of the brachial. It commences in the ante-cubital fossa, opposite the neck of the radius, and terminates in the palm of the hand, where it anastomoses with the superficialis volæ to form the superficial palmar arch.

From its origin it runs obliquely downwards and inwards, beneath the muscles arising from the internal condyle, to the junction of the upper and middle thirds of the forearm, where it comes into relation with the ulnar nerve; it then descends vertically, on the radial side of the ulnar nerve, to the wrist, crosses in front of the main part of the annular ligament to the radial side of the pisiform bone, and enters the palm of the hand to form the main part of the superficial palmar arch.

Relations.—*Posterior.*—It rests, from above downwards, upon the lower part of the brachialis anticus, the flexor profundus digitorum, and the deep portion of the anterior annular ligament. *Anterior.*—In front it is crossed, in the oblique part of its course, by the pronator radii teres, the median nerve, which is separated from the artery by the deep head of the pronator, the flexor sublimis digitorum, the flexor carpi radialis, and the palmaris longus. In the middle third of the forearm it is overlapped by the anterior border of the flexor carpi ulnaris, and in the lower third it is covered by skin and fascia only. A short distance above the wrist the palmar cutaneous branch of the median nerve lies in front of it, and as it crosses the anterior annular ligament, it is bound down by a fascial expansion from the tendon of the flexor carpi ulnaris. Two venæ comites, which frequently communicate with one another, lie one on either side of the artery. *Lateral.*—On the *radial side* there is also, in its lower two-thirds, the flexor sublimis digitorum. On its *ulnar side* there is the flexor carpi ulnaris, from which, however, it is partially separated in its lower two-thirds by the ulnar nerve.

Branches.—(1) The **anterior ulnar recurrent** is a small branch which arises in the ante-cubital fossa, frequently in common with the posterior ulnar recurrent. It passes upwards to the front of the internal condyle, under cover of the pronator radii teres, and anastomoses with branches of the anastomotic and inferior profunda arteries.

(2) The **posterior ulnar recurrent branch**, larger than the anterior, arises in the ante-cubital fossa, from the outer side of the ulnar artery, and ascends on the brachialis anticus, and under cover of the muscles which rise from the internal condyle to the back of that prominence, where it passes between the humeral and olecranoid heads of the flexor carpi ulnaris, and anastomoses with the inferior profunda and anastomotic arteries. It gives branches to the adjacent muscles and to the elbow-joint.

(3) The **common interosseous artery** (a. interossea communis), a short trunk which springs from the inner and back part of the ulnar artery in the lower part of the ante-cubital fossa. It passes backwards towards the upper border of the interosseous membrane, and divides into anterior and posterior interosseous branches.

(3*a*) The **anterior interosseous artery** (a. interossea volaris) descends in front of the interosseous membrane, between the adjacent borders of the flexor longus pollicis and the flexor profundus digitorum, to the upper border of the pronator quadratus, where it pierces the interosseous membrane, and continues its descent, first on the posterior surface of the membrane, under cover of the extensor longus pollicis and extensor indicis, and then on the radius, in the groove for the extensor communis digitorum, to the back of the carpus, where it terminates in the posterior carpal arch. Whilst in front of the interosseous membrane it is accompanied by the anterior interosseous nerve, and afterwards by the posterior interosseous nerve.

Branches.—(*a*) **Nutrient** to the radius and ulna; (*b*) **Muscular** to the adjacent muscles; (*c*) The **anterior communicating**, a slender branch which descends behind the pronator quadratus and in front of the interosseous membrane to anastomose with the anterior carpal arch; (*d*) Small **anastomotic branches** are given off at the back of the forearm to anastomose with the posterior or interosseous artery; (*e*) The **comes nervi mediani** (a. mediana) is a long slender branch which rises from the upper part of the artery and descends in the front of the median nerve to the palm, where it anastomoses with recurrent branches of the superficial palmar arch.

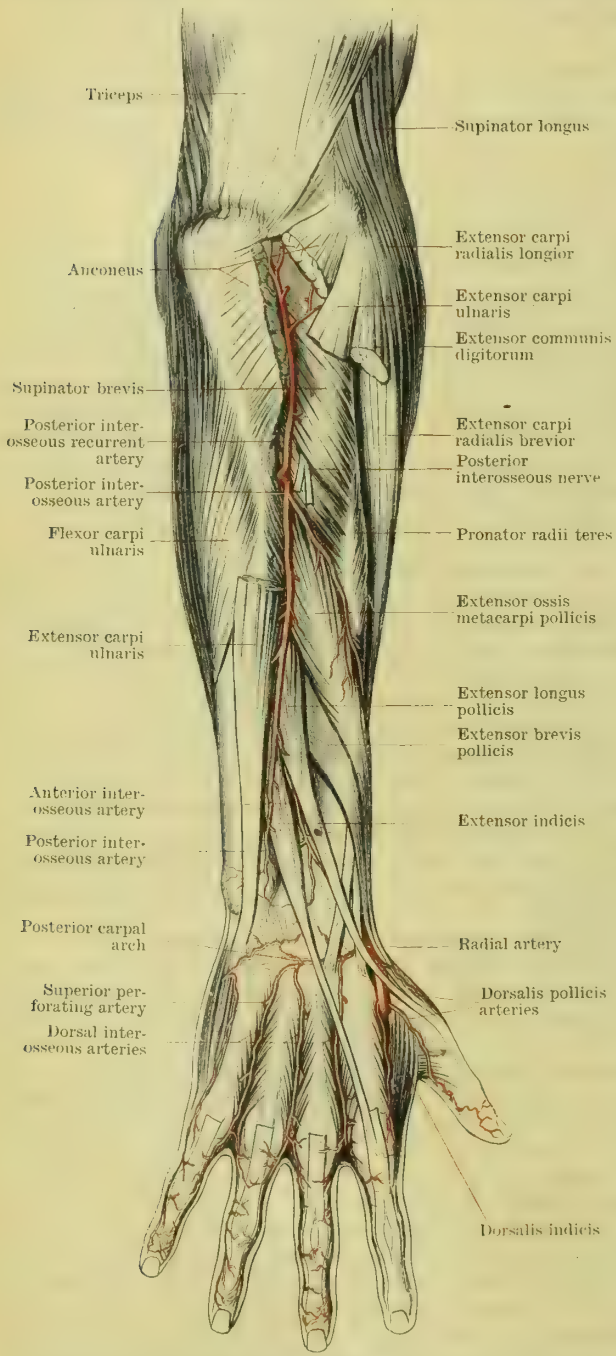


Fig. 565.—The Posterior Interosseous Artery and the Second Part of the Radial Artery, with their Branches.

(3*b*) The **posterior interosseous trunk** (a. interossea dorsalis) is usually smaller than the anterior interosseous. It passes backwards between the upper border of the interosseous membrane and the oblique ligament, and then between the supinator brevis and the extensor ossis metacarpi pollicis, after which it descends between the superficial and deep muscles on the back of the forearm to the wrist, where it anastomoses with the anterior interosseous artery and with the posterior carpal arch. As it crosses the extensor ossis metacarpi pollicis it is accompanied by the posterior interosseous nerve, but in the remainder of its course it is separated from the nerve by the deep muscles.

Branches.—(*a*) A **posterior interosseous recurrent** (a. interossea recurrens) branch is given off as soon as the posterior interosseous artery has passed beneath the lower border of the supinator brevis. It ascends on the posterior surface of the supinator brevis, under cover of the anconeus, to the back of the external condyle of the humerus, where it anastomoses with the posterior terminal branch of the superior profunda and with branches of the anastomotic artery. (*b*) **Muscular branches** to both superficial and deep muscles on the back of the forearm. (*c*) **Cutaneous branches** to the skin on the back of the forearm and the back of the wrist.

(*d*) The **anterior ulnar carpal** (ramus carpeus volaris), a small branch given off above the anterior annular ligament, passes outwards beneath the flexor tendons and their sheaths on the anterior surface of the carpal ligaments, and anastomoses with the anterior carpal branch of the radial to form the anterior carpal arch.

(*e*) The **posterior ulnar carpal branch** (ramus carpeus dorsalis) arises from the back of the inner side of the ulnar artery just above the pisiform bone. It passes backwards beneath the flexor and extensor carpi ulnaris muscles to the back of the

carpus, where it unites with the posterior carpal branch of the radial to form the posterior carpal arch.

(*f*) **Profunda** (ramus volaris profundus). — This branch descends between the abductor and flexor brevis minimi digiti, and, turning outwards beneath the flexor brevis, the opponens minimi digiti, and the flexor tendons and their sheaths, joins the termination of the radial artery to complete the deep palmar arch.

The Arterial Arches of the Wrist and Hand.

Anterior Carpal Arch (Fig. 564). — The anterior carpal arch lies on the front of the carpus behind the flexor tendons and their synovial sheaths. It is formed by the union of the anterior carpal branches of the radial and ulnar arteries, and it receives the communicating branch from the anterior interosseous artery above and recurrent branches from the deep palmar arch below. The branches of distribution which pass from it are distributed to the ligaments and synovial membranes of the wrist and of the intercarpal and carpo-metacarpal joints.

Posterior or Dorsal Carpal Arch (Fig. 565).—This arch lies on the posterior carpal ligaments under cover of the extensor tendons and their sheaths. It is formed by the union of the dorsal carpal branches of the radial and ulnar arteries, and receives the terminations of the anterior and posterior interosseous arteries.

Branches.—(*a*) **Articular** to the adjacent articulations. (*b*) **Dorsal interosseous**, two slender branches which run downwards on the third and fourth dorsal interosseous muscles to the clefts of the fingers, where each divides into collateral branches. They communicate near their origins with the deep palmar arch by the superior perforating arteries, and near their terminations with the palmar digital vessels through the inferior perforating arteries. Their collateral terminal branches run downwards on the dorso-lateral aspects of the fingers which bound the third and fourth interosseous spaces, and they anastomose with the collateral digital branches of the palmar digital arteries.

Superficial Palmar Arch (arcus volaris superficialis, Fig. 563).—This arterial arch includes the terminal portion of the ulnar artery, and is usually completed externally by the superficialis volæ, or sometimes by the radialis indicis, or the princeps pollicis. It extends from the ball of the little finger to the inner border of the superficial head of the flexor brevis pollicis, and reaches as low down as a line drawn across the palm at the level of the lower border of the fully abducted thumb. It is covered by the integuments and the central portion of the palmar fascia, and, on the ulnar side of the palm, by the palmaris brevis, and it is accompanied by venæ comites. It is in contact behind with the flexor brevis and opponens minimi digiti, and with the digital branches of the ulnar and median nerves, as well as with the flexor tendons and the lumbrical muscles.

Branches.—**Four digital arteries** (aa. digitales volares communes) arise from the convexity of the arch. The innermost descends along the ulnar border of the little finger, accompanied by the internal digital branch of the ulnar nerve; the outer three pass downwards superficial to the digital nerves, along the middle of the three inner interosseous spaces towards the interdigital clefts, just above which each digital artery divides into **two collateral digital arteries** (aa. digitales volares propriæ), which supply the contiguous sides of the fingers bounding the cleft. As the collateral digital branches descend along the sides of the fingers they lie superficial to the corresponding digital nerves, and supply branches to the joints, to the flexor tendons with their sheaths, and to the skin and subcutaneous tissues on the palmar surface; they also send backwards dorsal branches which anastomose with the dorsal digital arteries and supply the tissues on the dorsal aspects of the second and terminal phalanges. Some of the backwardly-directed branches form a plexus in the matrix of the nail. In the pulp of the finger-tips anastomosing twigs join to form arches from which numerous branches are given off to the skin and subcutaneous fat.

Each of the outer three digital arteries is joined immediately above its division by a palmar interosseous branch from the deep palmar arch and an inferior communicating artery from the dorsal interosseous. The innermost digital artery is joined by a branch which comes either from the inner palmar interosseous artery or from the deep palmar arch.

Deep Palmar Arch (arcus volaris profundus, Fig. 564).—The deep palmar arch extends from the base of the metacarpal bone of the little finger to the upper end of the first interosseous space, and is formed by the terminal part of the radial artery, anastomosing with the deep branch of the ulnar. It is from half to three quarters of an inch (12 to 18 mm.) above the level of the superficial palmar arch, and it lies deeply in the palm, in contact with the bases of the metacarpal bones and ligaments and on the origin of the interossei muscles; it is under cover of the flexor tendons and their synovial sheaths.

Branches.—(*a*) The **superior perforating** (rami perforantes); three small arteries which pass backwards through the inner three interosseous spaces, and between the origins of the dorsal interossei muscles. They anastomose on the dorsum of the hand with the dorsal interosseous arteries.

(*b*) Small irregular **recurrent branches** pass upwards and unite with the anterior carpal arch.

(*c*) The **articular** to the adjacent articulations.

(*d*) The **palmar interosseous arteries** (aa. metacarpeæ volares) are three vessels which pass downwards on the interosseous muscles of the three inner spaces and under cover of the flexor tendons. They terminate by anastomosing with the palmar digital arteries just before the latter vessels divide into collateral branches.

(*e*) The **communicating**, a small irregular branch which passes inwards between the flexor tendons and the short muscles of the little finger to anastomose with the innermost palmar digital artery.

BRANCHES OF THE DESCENDING THORACIC AORTA.

The branches given off from the thoracic portion of the descending aorta are distributed chiefly to the walls of the thorax and to the thoracic viscera. They contribute also to the supply of the spinal cord and its membranes, and to that of the vertebral column and of the upper part of the abdominal wall. The branches, which are numerous and for the most part arranged in pairs, are as follows:—

Parietal.	Intercostal. Subcostal. Diaphragmatic. The vas aberrans.	**Visceral.**	Bronchial. Œsophageal. Pericardial. Mediastinal.

Parietal Branches of the Descending Thoracic Aorta.

1. **Intercostal Arteries** (a. intercostales).—There are nine pairs of aortic intercostal arteries. They usually arise separately, though not uncommonly a pair may take origin by a common trunk from the back of the aorta, and are distributed to the lower nine intercostal spaces, to the spinal column, to the contents of the spinal canal, and to the muscles and skin of the back. The third, fourth, and fifth on each side also give branches to the mammary gland. The arteries of opposite sides closely correspond, but, since the aorta in the thoracic region lies on the left side of the spinal column, the right intercostal arteries cross the front of the vertebral column, behind the œsophagus, the thoracic duct, and the vena azygos major, and are longer than the left arteries. In other respects the course of all the aortic intercostal arteries is almost identical. They run outwards and backwards on the sides of the bodies of the vertebræ to the intercostal spaces, passing behind the pleura, and being crossed, opposite the heads of the ribs, by the sympathetic cord. The lower arteries are also crossed by the splanchnic nerves, and those on the left side are in addition crossed by the smaller azygos veins. On reaching an intercostal space each artery runs upwards, sometimes behind, sometimes in front of the corresponding intercostal nerve, to the upper border of the space, along which it is continued in the subcostal groove. It lies at first between the pleura and the posterior intercostal membrane, immediately below the intercostal nerve; it then pierces the intercostal membrane, and runs between it and the external intercostal muscle as far as the angle of the rib, beyond which it is continued forward between the internal and external intercostal

muscles. In the subcostal groove the artery lies between the corresponding vein above and the intercostal nerve below, and it terminates in front by anastomosing with an anterior intercostal branch of the internal mammary or of the musculo-phrenic artery. The lower two intercostal arteries on each side extend beyond their spaces to the abdominal wall, and anastomose with branches of the superior epigastric, subcostal, and lumbar arteries.

Branches.—(*a*) **Dorsal** (ramus posterior).—As each artery enters its intercostal space it gives off a posterior or dorsal branch which passes backwards accompanied by the posterior primary division of a spinal nerve, internal to the superior costo-transverse ligament, between the necks of the ribs which bound the space, and between the adjacent transverse processes, to the vertebral groove, where it divides into internal and external terminal branches. The *internal branch* (ramus cutaneus medialis) passes backwards and inwards either over or through the multifidus spinæ, giving branches to the muscles between which it passes and to the vertebral column. The *external branch* (ramus cutaneus lateralis) runs outwards beneath the longissimus dorsi to the interval between it and the musculus accessorius. It terminates in the skin of the back, after giving branches to the adjacent muscles. A *spinal branch* (ramus spinalis) from each dorsal artery passes through the corresponding intervertebral foramen, and enters the spinal canal, to the contents and walls of which it is distributed. It divides into three branches —neural, post-central, and pre-laminar. The *neural branch* runs inwards on the roots of the spinal nerve, pierces the dura mater and arachnoid, and divides into branches some of which pass to the membranes of the cord, whilst others are continued on to reinforce the dorsal and ventral spinal arteries. The *post-central branch* divides into ascending and descending branches which, anastomosing with similar branches above and below, form a series of vertical arches on the back of the bodies of the vertebræ. The arches of opposite sides are connected by short transverse anastomoses. The *pre-laminar branch* is small, and its ascending and descending branches are distributed in a similar though less regular manner on the posterior wall of the spinal canal.

(*b*) A **collateral branch** springs from the trunk of each intercostal artery near the angle of the rib. It descends to the lower border of the intercostal space, along which it runs forwards to anastomose in front, like the intercostal artery itself, with a separate anterior intercostal branch of the internal mammary or musculo-phrenic artery. The collateral branches of the lower two intercostal arteries on each side are inconstant; when present they are small, and terminate in the abdominal wall.

(*c*) **Muscular branches** (rami musculares) to the adjacent muscles are given off both by the main trunk and its collateral branch.

(*d*) A **lateral cutaneous** (ramus cutaneus lateralis) offset from the intercostal artery accompanies the lateral cutaneous branch of the intercostal nerve.

In addition to the above-named branches the first aortic intercostal on each side anastomoses with the superior intercostal, and may supply the whole or the greater part of the second intercostal space, and the first right aortic intercostal frequently gives origin to the right bronchial artery. The upper three or four aortic intercostals on each side give branches to the mammary gland which anastomose with branches of the long thoracic and internal mammary arteries. Longitudinal anastomoses between adjacent intercostal arteries and their dorsal branches sometimes exist near the necks of the ribs, or near the transverse processes. These longitudinal anastomoses are of considerable morphological interest.

2. The **subcostal arteries** are the last pair of parietal branches given off from the thoracic aorta. They are in series with and very similar to the aortic intercostal arteries, but are situated below the last ribs. Each runs along the lower border of the twelfth rib in company with the last dorsal nerve. It passes beneath the ligamentum arcuatum externum to the abdomen, and there crosses in front of the quadratus lumborum, and behind the kidney and the adjacent part of the colon. It next pierces the aponeurosis of origin of the transversalis abdominis, and runs between the transversalis and the internal oblique muscles, anastomosing with the lower intercostals, with the lumbar arteries, and with branches of the superior epigastric artery.

3. **Diaphragmatic branches** (aa. phrenicæ superiores) are given off from the lower part of the thoracic aorta. They are small vessels which ramify on the upper surface of the diaphragm, and anastomose with branches of the superior phrenic and musculo-phrenic arteries.

4. The **vas aberrans** is a variable and inconstant branch of the thoracic aorta;

it represents the dorsal roots of the fourth and fifth right aortic arches of the embryo. When present it arises from the front and right side of the upper part of the main trunk near the upper bronchial artery, and passes upwards and to the right behind the œsophagus; it frequently anastomoses with the right superior intercostal artery, and it may be enlarged and form the first part of the right subclavian artery.

Visceral Branches of the Descending Thoracic Aorta.

1. The **bronchial branches** (aa. bronchiales) of the thoracic aortæ are usually two in number—an upper and a lower—and both pass to the left lung. The *upper left bronchial artery* arises from the front of the main trunk opposite the bifurcation of the trachea; the *inferior left bronchial artery* usually takes origin near the lower border of the left bronchus. Both vessels are directed downwards and outwards to the back of the bronchus, which they accompany, and, dividing similarly, they follow its ramifications in the lung. They not only supply the walls of the bronchial tubes and the substance of the lungs, but also give branches to the bronchial glands, the pulmonary vessels, the pericardium, and the œsophagus.

As a rule there is only one *right bronchial artery*, and it arises from the first right aortic intercostal artery: but it not uncommonly arises from the upper left bronchial artery, and more rarely it springs directly from the aorta. In its course and distribution it corresponds to the bronchial arteries of the left side.

2. The **œsophageal branches** (aa. œsophageæ) are variable; usually four or five small branches spring from the front of the aorta and pass forwards to the œsophagus, in the walls of which they ramify, anastomosing above with branches of the left bronchial and inferior thyroid arteries, and below with œsophageal branches of the coronary and phrenic arteries.

3. The **pericardial branches** (rami pericardiaci) consist of three or four small irregular vessels which are distributed on the surface of the pericardium.

4. Small **mediastinal branches** (rami mediastinales) pass to the areolar tissue and glands in the posterior mediastinal space, and to the posterior part of the diaphragm.

BRANCHES OF THE ABDOMINAL AORTA.

The branches of the abdominal portion of the aorta are distributed almost entirely to the walls and contents of the abdominal cavity, but some also supply small branches to the vertebral column, and to the contents of the spinal canal, and others are prolonged into the pelvis. They are divisible into parietal and visceral groups, both of which include paired and single (unpaired) vessels.

- **Parietal.**
  - **Paired.**
    - Inferior phrenic.
    - Lumbar
    - Common iliac.
  - **Single.** Middle sacral.
- **Visceral.**
  - **Paired.**
    - Suprarenal.
    - Renal.
    - Spermatic or ovarian.
  - **Single.**
    - Cœliac axis.
    - Superior mesenteric.
    - Inferior mesenteric.

Parietal Branches of the Abdominal Aorta.

1. The **inferior phrenic arteries** (aa. phrenicæ inferiores, Fig. 566) are two in number, and are of small size; they arise, either separately or by a common trunk, from the aorta immediately below the diaphragm, on the under surface of which they are distributed. Diverging from one another, each artery runs upwards and outwards on the corresponding crus of the diaphragm—that on the right side passing behind the inferior vena cava, that on the left behind the œsophagus—and just before reaching the central tendon of the diaphragm it divides into internal and external terminal branches. The *internal branch* of each artery runs forward and anastomoses with its fellow of the opposite side, forming an arch, convex forwards, along the front of the central tendon of the diaphragm. Offsets from this arch anastomose with the superior phrenic, musculo-phrenic, and internal

mammary arteries. The *external branch* passes outwards towards the lower ribs and anastomoses with the musculo-phrenic and lower intercostal arteries.

In addition to supplying the diaphragm each inferior phrenic artery frequently gives a **superior capsular branch** to the suprarenal body of its own side, and occasionally small hepatic branches pass through the coronary ligament to the liver. Further, the left artery gives branches to the œsophagus which anastomose with

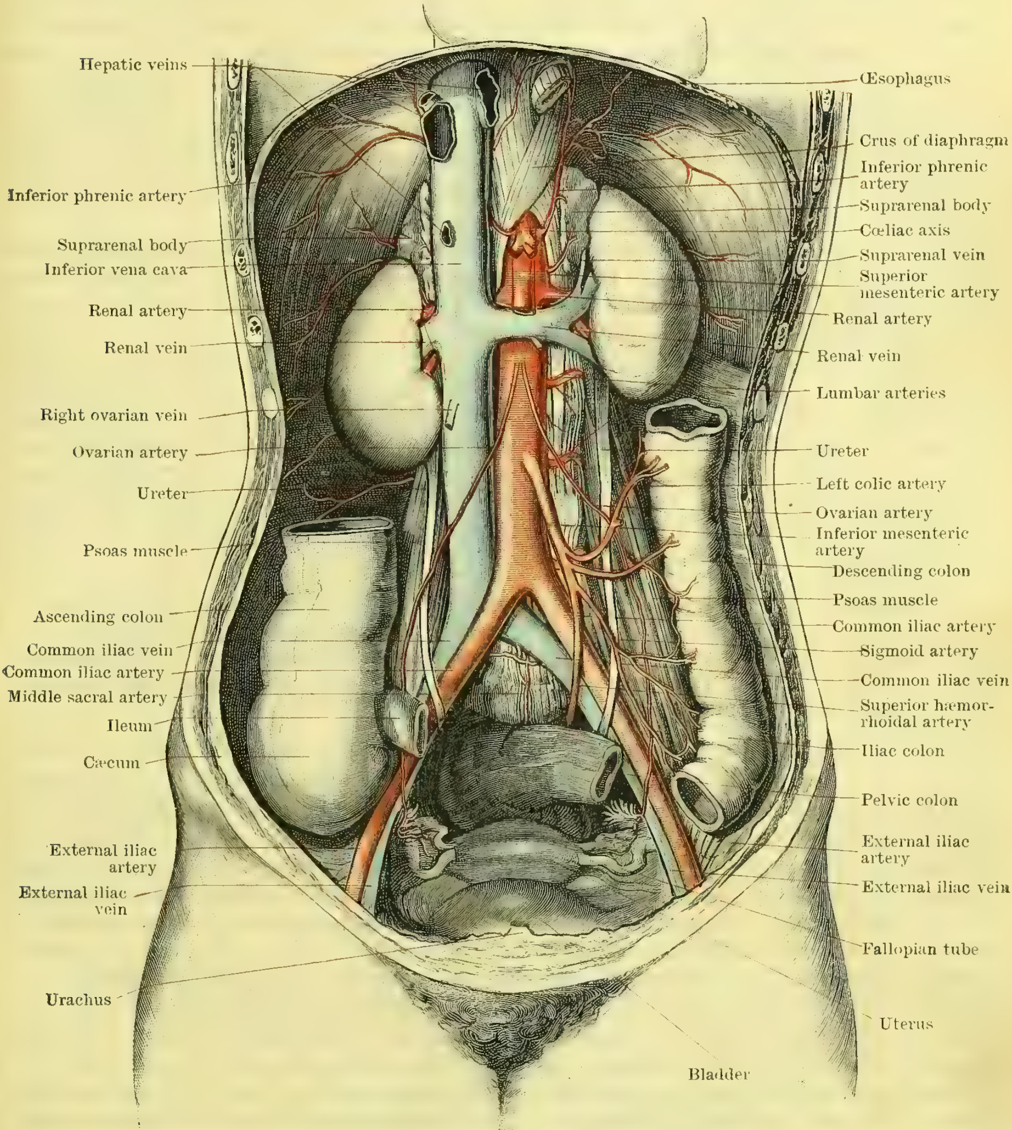


FIG. 566.—THE ABDOMINAL AORTA AND ITS BRANCHES.

œsophageal branches of the aorta and of the coronary artery, whilst from the artery of the right side minute branches pass to the inferior vena cava.

2. The **lumbar arteries** (aa. lumbales) correspond to the intercostal branches of the thoracic aorta. They are in series with them, their distribution is very similar, and, like the intercostals, they arise, either separately or by common trunks, from the back of the aorta.

There are usually four pairs of lumbar arteries, but occasionally a fifth pair arises from the middle sacral artery.

From their origins the lumbar arteries pass backwards and outwards on the front and sides of the bodies of the upper four lumbar vertebræ to the interval

between the adjacent transverse processes, beyond which they are continued in the abdominal wall.

They lie on the bodies of the corresponding lumbar vertebræ. In their backward course, and while still in relation with the vertebral bodies, each artery is crossed by the sympathetic cord, and then, passing under and being protected by the fibrous arches from which the muscle arises, it runs behind the psoas muscle and the lumbar plexus. The upper two arteries on each side also pass behind the crura of the diaphragm. Beyond the interval between the transverse processes of the vertebræ each artery turns outwards and crosses the quadratus lumborum—the last usually passing in front, and the others behind the muscle; it then pierces the aponeurosis of origin of the transversalis, and proceeds forwards in the lateral abdominal wall in the interval between the transversalis and internal oblique muscles. The lumbar arteries anastomose with one another, with the lower intercostal and subcostal arteries, and with branches of the superior and deep epigastric and of the deep circumflex iliac and ilio-lumbar arteries.

Fine twigs also pass from the lumbar arteries to the extra-peritoneal fat, and anastomose with corresponding branches from the inferior phrenic and ilio-lumbar arteries, and with small branches from the hepatic, renal, and colic arteries, to form the subperitoneal plexus of Turner.

The abdominal aorta lies somewhat to the left of the middle line, and consequently the right lumbar arteries are a little longer than the left, but the differences between the arteries of opposite sides are limited to the first parts of the main trunks. On the right side the arteries, which near their origins lie more in front of the vertebral bodies, pass behind the inferior vena cava, the upper two arteries being separated from this vessel by the right crus of the diaphragm. The upper two right arteries also pass behind the receptaculum chyli and the lower end of the large azygos vein.

Branches.—**Dorsal** (ramus dorsalis).—Each lumbar artery gives off, opposite the interval between the vertebral transverse processes, a dorsal branch of considerable size. It is analogous with and distributed like the corresponding branch of an aortic intercostal artery (p. 793). **Muscular branches** are given off, both from the main trunk and its dorsal branch, to the adjacent muscles.

3. The **middle sacral artery** (a. sacralis media, Fig. 566) is a single median vessel. It is commonly regarded as a caudal aorta and as the direct continuation of the abdominal aorta. It is, however, of small size, and almost invariably arises from the back of the aorta about half-an-inch above its bifurcation. It descends in front of the two lower lumbar vertebra and of the sacrum and coccyx, and ends opposite the tip of the last-named bone by anastomosing with the lateral sacral arteries to form a loop from which branches pass to the coccygeal body. In its course it passes at first behind the lower part of the abdominal aorta. Opposite the fifth lumbar vertebra it is crossed by the left common iliac vein, below which it is covered by peritoneum and coils of small intestine as far as the third sacral segment, and in the rest of its extent by the rectum. It is accompanied below by venæ comites, which, however, unite above to form a single middle sacral vein.

Small parietal branches pass transversely outwards on each side to the last lumbar vertebra and to the sacrum. They anastomose with the lateral sacral arteries, and they usually give off small spinal offsets which enter the anterior sacral foramina. Small and irregular visceral branches pass to the rectum and anastomose with the superior and middle hæmorrhoidal arteries.

COMMON ILIAC ARTERIES.

4. The **common iliac arteries** (aa. iliacæ communes, Figs. 566 and 572) are the terminal branches of the abdominal aorta. They are formed by the bifurcation of the main trunk, and commence opposite the middle of the body of the fourth lumbar vertebra a little to the left of the middle line. Each artery passes downwards and outwards across the bodies of the fourth and fifth lumbar vertebræ and the intervening intervertebral disc, and terminates in front of the correspond-

ing lumbo-sacral articulation by becoming the internal iliac artery; at the same time it gives off the external iliac artery to the lower extremity.

The direction of each common iliac is well indicated by a line drawn from the bifurcation of the aorta to a point midway between the symphysis pubes and the anterior superior spine of the ilium.

The angle included between the two diverging trunks is about 60° in the male and about 68° in the female.

The right artery is, for obvious reasons, a little longer than the left; the former is about two inches, and the latter one and three-quarter inches in length.

Relations.—*Anterior.*—Both arteries are covered by peritoneum, and are separated by it from coils of the small intestine. Communicating branches between the aortic and hypogastric plexuses of the sympathetic pass in front of the arteries, each of which is also crossed near its termination by the corresponding ureter.

The left artery is in addition crossed in front by the superior hæmorrhoidal vessels.

Posterior.—Behind the artery of each side are the bodies of the fourth and fifth lumbar vertebræ, with the intervertebral disc above and below the latter, the psoas muscle, and the sympathetic cord. These relationships, however, are much closer on the left side than on the right. The right common iliac, except at its lower end, where it is in contact with the psoas, is separated from the structures named by the terminations of the right and left common iliac veins and the commencement of the inferior vena cava. The left common iliac, which is not so separated, lies on the inner border of the psoas. Somewhat deeply placed in the areolar tissue between the psoas and the lumbar vertebra, the obturator nerve, the lumbo-sacral cord, and the ilio-lumbar artery form posterior relations to the artery on both sides.

Lateral.—On both sides of each artery are coils of small intestine. The commencement of the inferior vena cava lies to the outer side of the upper part of the right artery, and on the inner side of this vessel are the right common iliac vein below and the left common iliac vein above. The last-named vein lies on the inner side of the left artery.

The Paired Visceral Branches of the Abdominal Aorta.

1. **Suprarenal** or **Capsular Arteries** (aa. suprarenales, Fig. 566).—There are three sets of suprarenal arteries—the superior, middle, and inferior. Of these the middle only arise from the aorta direct; the superior spring from the inferior phrenic, and the inferior from the renal arteries.

The middle suprarenal arteries are two small branches which arise, behind the pancreas, from the sides of the aorta, close to the origin of the superior mesenteric artery. They run, one on each side, outwards and upwards upon the crura of the diaphragm, and just above the renal arteries, to the suprarenal bodies to which they are distributed, and they anastomose with the superior and inferior suprarenal arteries.

2. **Renal Arteries** (aa. renales, Fig. 566).—The renal arteries arise, one on each side, from the aorta, about half-an-inch below the origin of the superior mesenteric artery and opposite the first lumbar vertebra.

Both arteries are of large size, and the right, which is a little longer than the left, is frequently slightly lower in position. Each artery runs almost transversely outwards to the hilus of the corresponding kidney. It passes in front of the crus of the diaphragm and of the upper part of the psoas muscle. The left artery lies behind the pancreas; the right vessel passes behind the inferior vena cava, the head of the pancreas, and the second part of the duodenum. The renal vein usually lies below and in front of the artery, but near the kidney the vein not unfrequently occupies a posterior position.

On reaching the hilus of the kidney each artery divides into three branches, two of which pass in front of the pelvis of the ureter, and between it and the renal vein, and the third behind the pelvis. In the renal sinus these primary branches break up into numerous secondary branches which enter the kidney substance between the pyramids.

Branches.—The following branches are given off by each renal artery, in addition to the terminal branches:—

(*a*) **Inferior suprarenal** (a. suprarenalis inferior), which passes upwards to the lower part of the suprarenal body.

(*b*) **Ureteral.**—Small branches to the upper part of the ureter, which anastomose with branches of the spermatic or ovarian arteries.

(*c*) **Peri-renal.**—Small branches to the fatty capsule of the kidney, which anastomose with the lumbar arteries.

(*d*) **Glandular offsets,** either from the main trunk or from some of its branches, pass to the renal and lumbar glands.

3*a*. **Spermatic Arteries** (aa. spermaticæ internæ).—The spermatic arteries in the male, and the corresponding ovarian arteries (aa. ovaricæ) in the female, are two long slender vessels, one on the right side and one on the left, which arise from the front of the abdominal aorta, a short distance below the origins of the renal arteries.

Each spermatic artery runs downwards and outwards to the internal abdominal ring; it then traverses the inguinal canal, and consequently takes a downward and inward course. On emerging from the canal, through the external abdominal ring, it enters the scrotum, in which it descends, almost vertically, but in a tortuous manner, to end immediately above the testicle by dividing into testicular and epididymal branches.

Relations.—In the abdominal cavity the arteries lie behind the peritoneum, to which they are closely attached, and in front of the psoas muscles. The right artery is also in front of the inferior vena cava. Each artery descends in front of the ureter, the genito-crural nerve, and the lower end of the external iliac artery of its own side, and is accompanied by two spermatic veins which unite above into a single trunk. The anterior relations differ on the two sides. The right artery lies behind, and is crossed, by the ileo-colic, the right colic, and the terminal branches of the superior mesenteric artery, and by the third part of the duodenum, the termination of the ileum, and the vermiform appendix. The left artery is crossed in front by the left colic and sigmoid branches of the inferior mesenteric artery and by the iliac colon.

At the internal abdominal ring the spermatic artery comes into relation, at its inner side, with the vas deferens. The two structures run together round the outer and anterior aspects of the deep epigastric artery to the inguinal canal.

In the inguinal canal the spermatic artery, along with the other constituents of the spermatic cord, is enclosed in the infundibular and cremasteric fasciæ, the intercolumnar fascia being added at the external abdominal ring. In this part of its course the artery lies in front of the vas deferens, and behind the anterior part of the pampiniform plexus and the spermatic veins which arise from it.

Branches.—(*a*) **Ureteral branches,** small in size, are distributed to the middle part of the ureter, anastomosing above with branches from the renal and below with branches from the vesical arteries.

(*b*) **Cremasteric branches,** given off in the inguinal canal and upper part of the scrotum, supply the cremaster muscle, and anastomose with the cremasteric branch of the deep epigastric.

(*c*) **Terminal Branches.**—(i.) The *epididymal branch* runs downwards to the epididymis, which it supplies. It also gives twigs to the vas aberrans, the coni vasculosi, and the tunica vaginalis, and anastomoses with the artery of the vas deferens. (ii.) The *testicular branch* descends on the upper and back part of the testicle, and breaks up into numerous peripheral and central branches. The peripheral branches pass through the tunica albuginea and ramify on its inner surface; they anastomose with one another and with the central branches. The central branches pass through the mediastinum testis and along the surfaces of the septa.

3*b*. The **ovarian arteries** (aa. ovaricæ, Fig. 566) in the female closely correspond to the spermatic arteries in the male. They are, however, much shorter, and, instead of passing through the abdominal wall, descend into the pelvis, where they run between the layers of the broad ligament to terminate between the ovaries and the uterus by anastomosing with the uterine arteries.

Relations.—In the upper part of their course the relations of the ovarian arteries are like those of the spermatic arteries, but about the level of the anterior superior spine of the ilium each ovarian artery turns inwards, and, crossing the upper part of the external iliac vessels (artery and vein), descends in the anterior border of the fossa ovarii, on the lateral wall of the pelvis, to the broad ligament, where it is placed below the Fallopian tube.

Branches.—(*a*) **Ureteral,** to the middle part of the ureter.

(*b*) **Tubal,** to the Fallopian tube, which anastomose with branches of the uterine.

(*c*) **Ligamentous,** to the round ligament, as far as the inguinal canal.

(*d*) **Ovarian branches**, numerous, pass to the hilus of the ovary, and thence to the substance of the organ.

(*e*) A **uterine branch** is formed by the continuation of the trunk to its anastomoses with the uterine branch of the internal iliac.

The Unpaired or Single Visceral Branches of the Abdominal Aorta

1. The **cœliac artery** or **cœliac axis** (a. cœliaca, Figs. 566 and 567) arises from the front of the abdominal aorta, immediately below the aortic orifice of the diaphragm and between its crura. It is a short but wide vessel which runs almost horizontally forwards for a distance of about half-an-inch and then terminates by dividing into three large branches—the coronary or gastric, the hepatic, and the splenic.

Relations.—The short trunk extends from the aorta behind the lesser sac of peritoneum, by which it is separated from the stomach, or from the small omentum, in front. It runs below the right lobe of the liver, and above the upper border of the pancreas and the splenic vein, and it is surrounded by the solar and cœliac plexuses of the

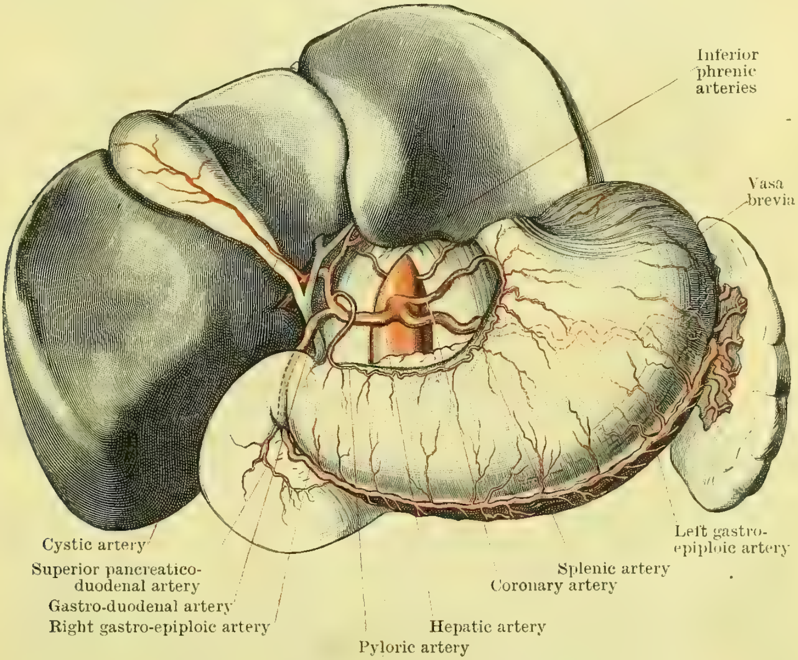


Fig. 567.—The Cœliac Axis and its Branches.

sympathetic; the right semilunar ganglion and Spigelian lobe of the liver are on its right side, and the left semilunar ganglion and cardiac end of the stomach are on its left side

Branches.—(*a*) The **coronary** or **gastric artery** (a. gastrica sinistra) is the smallest branch of the cœliac axis. It runs obliquely upwards and to the left, and reaches the smaller curvature of the stomach close to the œsophagus. It then turns sharply forwards, downwards, and to the right, and runs towards the pyloric end of the stomach to anastomose with the pyloric branch of the hepatic artery. In the first part of its course the artery lies behind the lesser sac of the peritoneum; it then passes into the right pancreatico-gastric fold, and is continued between the layers of the small omentum.

Branches.—(i.) **Œsophageal** (rami œsophagei).—When the artery reaches the stomach a large œsophageal branch is given off, which passes upwards on the œsophagus, and gives offsets to it which anastomose with œsophageal branches of the thoracic aorta and with branches of the inferior phrenic. (ii.) **Gastric branches** are distributed to both surfaces of the stomach. They anastomose with branches of the vasa brevia of the splenic, and with branches of the gastro-epiploic arterial arch on the greater curvature of the stomach.

(*b*) The **splenic artery** (a. lienalis, Fig. 567) is the largest branch of the

cœliac axis. It runs a more or less tortuous course behind the stomach and the lesser sac of the peritoneum, and along the upper border of the pancreas. It lies in front of the left suprarenal capsule and the upper end of the left kidney, and passes forwards between the two layers of the lieno-renal ligament, where it divides into from five to eight terminal branches (rami lienales), which enter the hilus of the spleen and supply the splenic substance. It is accompanied by the splenic vein, which lies below it.

Branches.—(i.) **Pancreatic** (rami pancreatici).—Numerous small branches (pancreatica parvæ) are given off to the pancreas. One large branch (pancreatica magna), occasionally present, enters the upper border of the pancreas, about the junction of its middle and left thirds, and runs from left to right in the substance of the pancreas, a little above and behind the pancreatic duct. Both the small and large arteries supply the substance of the pancreas, and anastomose with one another and with branches of the pancreatico-duodenal arteries.

(ii.) The **vasa brevia** (aa. gastricæ breves), or short gastric branches, four or five in number, are given off either from the end of the main vessel or, more commonly, from some of its terminal branches. They pass between the layers of the gastro-splenic omentum to the left end of great curvature of the stomach, and anastomose with the œsophageal, the gastric, and the left gastro-epiploic arteries.

(iii.) The **left gastro-epiploic branch** (a. gastro-epiploica sinistra) arises from the front of the splenic, close to its termination, and passes forwards between the layers of the gastro-splenic omentum to the left end of the great curvature of the stomach, along which it is continued, from left to right, between the layers of the gastro-colic or great omentum. It ends by anastomosing with the right gastro-epiploic artery, and it gives off numerous gastric branches to both surfaces of the stomach, which anastomose with the vasa brevia and with branches of the coronary and pyloric arteries. Long slender omental branches pass to the omentum and anastomose with branches of the colic arteries.

(*c*) The **hepatic artery** (a. hepatica, Fig. 567) runs along the upper border of the head of the pancreas to the right pancreatico-gastric fold of peritoneum, in which it turns forwards to the upper border of the first part of the duodenum. It then passes upwards, between the layers of the small omentum, in front of the portal vein and to the left of the common bile duct, and reaches the transverse fissure of the liver, where it divides into right and left branches.

Branches.—(i.) The **pyloric artery** (a. gastrica dextra) is a small branch which arises opposite the upper border of the first part of the duodenum. It descends to the pylorus, running between the layers of the small omentum, and then turns to the left along the smaller curvature of the stomach. It gives branches to both surfaces of the stomach, and terminates by anastomosing with the coronary artery.

(ii.) The **gastro-duodenal artery** (a. gastro-duodenalis).—This branch of the hepatic arises just above the upper border, descends behind, and terminates opposite the lower border of the first part of the duodenum. In its course it lies between the neck of the pancreas and the first part of the duodenum, and it is in front of the portal vein. The common bile duct is on its right side. The vessel ends by dividing into the right gastro-epiploic and the superior pancreatico-duodenal arteries. The **right gastro-epiploic artery** (a. gastro-epiploica dextra) is the larger of the two terminal branches of the gastro-duodenal; it passes from right to left along the greater curvature of the stomach, between the layers of the gastro-colic omentum, and unites with the left gastro-epiploic branch of the splenic artery. From the arterial arch so formed branches pass upwards on both surfaces of the stomach, and anastomose with branches of the pyloric and coronary arteries. Other branches pass downwards to the omentum, and anastomose with branches of the colic arteries. The **superior pancreatico-duodenal artery** (a. pancreatico-duodenalis superior) runs a short course to the right, between the duodenum and the head of the pancreas, and divides into anterior and posterior terminal branches which descend, the former in front of and the latter behind the head of the pancreas, to anastomose with similar branches of the inferior pancreatico-duodenal artery. They supply the head of the pancreas, anastomosing in it with the pancreatic branches of the splenic artery; branches are also given to the second part of the duodenum and to the common bile duct.

(iii.) **Terminal branches.**—The **right hepatic artery** (ramus dexter) passes either in front of or behind the hepatic duct and behind the cystic duct, to the right end of the transverse fissure of the liver, where it divides into two or more branches which enter the

substance of the liver and accompany the branches of the portal vein and the hepatic duct. As it crosses just above the junction of the hepatic and cystic ducts, the right hepatic artery gives off a cystic branch. The *cystic artery* (a. cystica) runs downwards and forwards along the cystic duct to the gall-bladder, where it divides into upper and lower branches; the upper passes downwards between the gall-bladder and the under surface of the liver, to both of which it gives offsets; the lower branch is distributed on the under surface of the gall-bladder, between it and the peritoneum. The **left hepatic artery** (ramus sinister) is longer and narrower than the right. It runs to the left end of the transverse fissure, gives one or two branches to the Spigelian lobe, crosses the

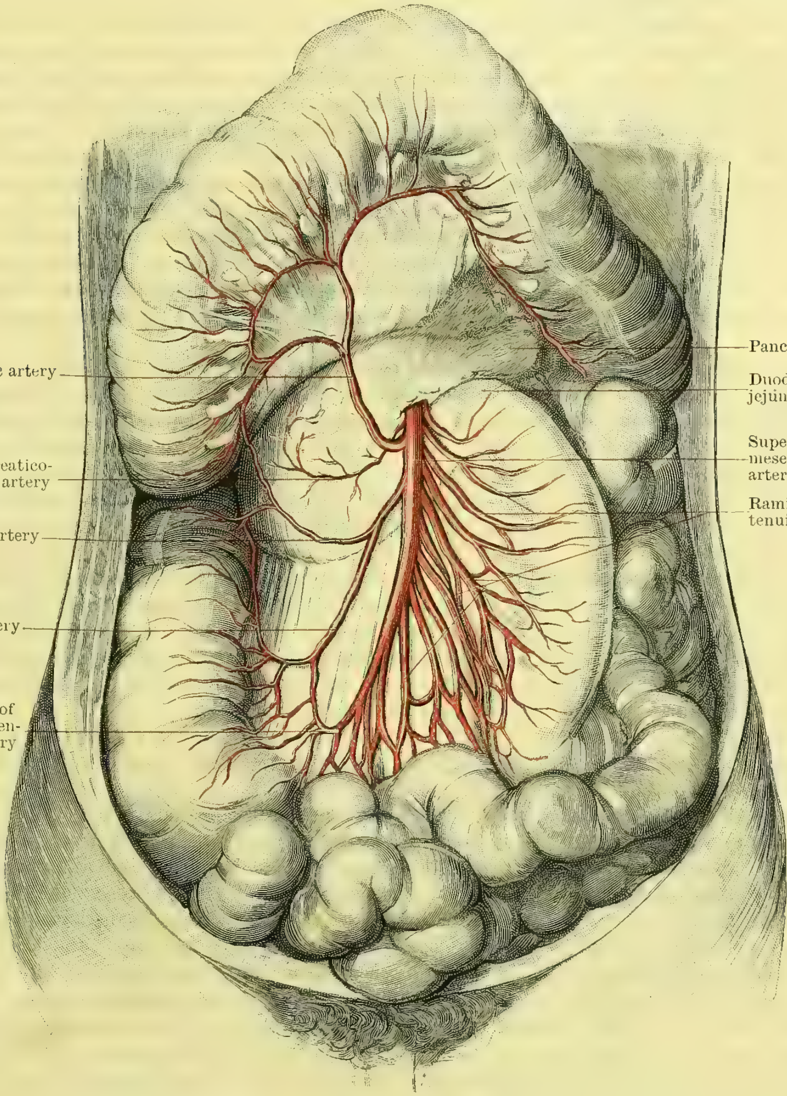


FIG. 568.—THE SUPERIOR MESENTERIC ARTERY AND ITS BRANCHES.

longitudinal fissure, and breaks up into branches which terminate in the substance of the left lobe of the liver.

2. The **superior mesenteric artery** (a. mesenterica superior, Figs. 566, 568, and 591) springs from the front of the aorta, about half-an-inch below the origin of the cœliac axis and opposite the first lumbar vertebra.

It passes obliquely downwards and forwards, crossing in front of the left renal vein, the lower part of the head of the pancreas, and the third part of the duodenum; opposite the latter it enters the root of the mesentery, in which it continues to descend, curving obliquely from above downwards and to the right, to

the right iliac fossa, and crossing in this part of its course obliquely in front of the aorta, the lower part of the inferior vena cava, the right ureter, and the right psoas muscle. At its origin it lies behind the body of the pancreas and the splenic vein; where it passes in front of the duodenum it is crossed anteriorly by the transverse colon, and in the lower part of its extent it is concealed by coils of small intestine.

Branches.—It gives off numerous branches which supply the duodenum and the pancreas in part, the whole of the small intestine below the duodenum, and the large intestine nearly as far as the splenic flexure.

The branches are as follows:—

(*a*) **Rami intestini tenuis** (aa. intestinales), or branches to the small intestine, varying from ten to sixteen in number; they spring from the convexity of the superior mesenteric artery, and pass obliquely forwards and downwards between the layers of the mesentery, each dividing into two branches which anastomose with adjacent branches to form a series of arcades from which secondary branches are given off. This process of division and union is repeated three or four times; thus four or five tiers of arches are formed, from the most distal of which terminal branches are given off to the walls of the jejunum and ileum. Branches from the successive arcades are also given off to the mesenteric glands. The terminal branches anastomose together in the walls of the gut, forming a vascular network which communicates above with the inferior pancreatico-duodenal artery and below with the terminal branch of the superior mesenteric trunk. The vascular loops and branches are accompanied by corresponding veins, lymphatics, and nerves.

(*b*) The **inferior pancreatico-duodenal artery** (a. pancreatico-duodenalis inferior). It arises either from the trunk of the superior mesenteric, at the upper border of the third part of the duodenum, or from the first of the rami intestini. It runs to the right, between the head of the pancreas and the third part of the duodenum, and terminates by dividing into two branches, anterior and posterior, which ascend, the former in front and the latter behind the head of the pancreas; they supply the head of the pancreas, the third part of the duodenum, and they anastomose with the similar branches of the superior pancreatico-duodenal artery.

(*c*) The **middle colic artery** (a. colica media) is a large branch which springs from the front of the superior mesenteric as it enters the root of the mesentery. It runs downwards and forwards in the transverse mesocolon, and terminates by dividing into two branches, right and left, which anastomose respectively with the right and left colic arteries, forming arcades from which secondary and tertiary loops are derived, the terminal branches being distributed to the walls of the transverse colon.

(*d*) The **right colic artery** (a. colica dextra) springs from the right or concave side of the superior mesenteric, either alone or in the form of a common trunk which divides into right and ileo-colic branches. It runs to the right, behind the peritoneum on the posterior wall of the abdomen, and in front of the right psoas, the ureter, and the spermatic or ovarian vessels, towards the ascending colon, near which it divides into an ascending and a descending branch. The former passes upwards, and anastomoses in the transverse mesocolon with the middle colic artery. The latter descends to anastomose with the upper branch of the ileo-colic, and from the loops thus formed branches are distributed to the walls of the ascending colon and the beginning of the transverse colon.

(*e*) The **ileo-colic artery** (a. ileo-colica) arises by a common trunk with the right colic, or separately from the right side of the superior mesenteric, and passes downwards and outwards, behind the peritoneum, towards the lower part of the ascending colon, where it terminates by dividing into an ascending branch which anastomoses with the lower branch of the right colic, and a descending branch which communicates with the ileo-cæcal terminal branches of the superior mesenteric trunk.

(*f*) **Terminal.**—The lower end of the superior mesenteric artery divides into five branches—(i.) ileal, (ii.) appendicular, (iii.) anterior ileo-cæcal, (iv.) posterior ileo-cæcal, and (v.) colic.

The **ileal branch** (a. ilea) turns upwards and to the left in the lowest part of the mesentery, and anastomoses with the rami intestini. The **appendicular branch** (a. appendicularis) passes behind the terminal portion of the ileum, and through the meso-appendix to the vermiform process, upon which it ends. The **anterior ileo-cæcal** crosses the front of the ileo-cæcal junction in a fold of peritoneum; the **posterior ileo-cæcal** crosses the ileo-cæcal junction posteriorly, and the **colic** runs upwards to the ascending colon. The ileo-cæcal branches supply the walls of the cæcum, and, like the colic branch, anastomose with branches of the ileo-colic artery.

3. The **inferior mesenteric artery** (a. mesenterica inferior, Fig. 566) arises

from the front and towards the left side of the aorta an inch and a half above the bifurcation; it passes downwards and slightly outwards, lying behind the peritoneum and on the front of the left psoas muscle, to the upper and outer border of the left common iliac artery, where it becomes the superior hæmorrhoidal.

Branches.—(*a*) The **left colic artery** (a. colica sinistra) arises from the left side of the inferior mesenteric near its origin. It runs upwards and to the left towards the splenic flexure of the colon, where it divides into ascending and descending branches. The ascending branch crosses in front of the lower end of the left kidney, passes between the layers of the transverse mesocolon, and, turning inwards, terminates by joining the left branch of the middle colic artery. The descending branch passes downwards behind the peritoneum to the inner side of the descending colon to unite with the superior sigmoid artery, and from the loops thus formed branches are distributed to the descending colon.

In the whole of its course the left colic artery lies behind the peritoneum, and on the posterior abdominal wall; it crosses in front of the left psoas, the left ureter, and the lower end of the left kidney.

(*b*) The **sigmoid branches** (aa. sigmoideæ), usually two in number, arise from the convexity of the inferior mesenteric, and pass downwards and outwards to the iliac colon. They lie behind the peritoneum, and in front of the psoas, the ureter, and the upper part of the iliacus. They terminate by dividing into branches which anastomose with the left colic above and with branches of the superior hæmorrhoidal below, forming a series of arches from which branches are distributed to the lower part of the descending colon, the iliac colon, and the pelvic colon.

(*c*) The **superior hæmorrhoidal artery** (a. hæmorrhoidalis superior) is the direct continuation of the inferior mesenteric. It enters the mesentery of the pelvic colon, crosses the front of the left common iliac artery, descends into the pelvis as far as the third piece of the sacrum, or in other words the junction between the pelvic colon and the rectum, and divides into two branches which pass downwards on the sides of the rectum. Half-way down the rectum each of the two terminal branches of the superior hæmorrhoidal artery divides into two or more branches which pass through the muscular coats and terminate in the submucous tissue, where they divide into numerous small branches which pass vertically downwards, anastomosing with each other, with offsets from the middle hæmorrhoidal branches of the internal iliac arteries, the inferior hæmorrhoidal branches of the internal pudic arteries, and with branches from the middle sacral artery.

The superior hæmorrhoidal artery supplies the mucous membrane of the pelvic colon and the rectum and the muscular coats of the pelvic colon.

THE INTERNAL ILIAC ARTERY.

The **internal iliac** or **hypogastric artery** (a. hypogastrica, Figs. 566, 569, and 572) in the fœtus is the direct continuation of the common iliac trunk. It supplies numerous branches to the pelvis, runs upwards on the anterior abdominal wall to the umbilicus, and is prolonged as the umbilical artery to the placenta. One of its pelvic branches—the sciatic—is at first the main artery of the inferior extremity, but subsequently another branch is given off which becomes the chief arterial trunk of the lower limb. This branch is the external iliac artery; it soon equals and ultimately exceeds the internal iliac in size, and it is into these two vessels that the common iliac appears to bifurcate.

When the placental circulation ceases and the umbilical cord is severed, the part of the internal iliac trunk which extends from the pelvis to the umbilicus atrophies, and is afterwards represented almost entirely by a fibrous cord, known as the obliterated hypogastric artery. It is only at its proximal end that the atrophied part remains pervious, and here it forms the commencement of the superior vesical artery; accordingly, the permanent internal iliac artery is a comparatively short vessel. Owing to the arrangement of some of its branches it appears to end in an anterior and a posterior division, the former of which is to be regarded as the continuation of the vessel to the obliterated hypogastric, whilst the latter is simply a common stem of origin for some of the branches.

With this explanation the internal iliac artery may be described in the usual manner.

It arises from the common iliac opposite the lumbo-sacral articulation, and

descends into the pelvis, to terminate, as a rule, opposite the upper border of the great sciatic notch, in two divisions—anterior and posterior—from each of which branches of distribution are given off. The artery measures about one and a half inches in length, and is the inner of the two terminal branches of the common iliac artery.

Relations.—*Anterior.*—The artery on each side is covered in front and internally by peritoneum, under which the corresponding ureter descends along the anterior border of the artery. The rectum crosses from the front to the inner side of the left artery, and the terminal part of the ileum bears the same relation to the right artery.

Posterior to it are the internal iliac vein and the commencement of the common iliac vein; behind these is the lumbo-sacral cord and the sacrum.

Lateral.—On its outer side the external iliac vein separates it from the psoas muscle

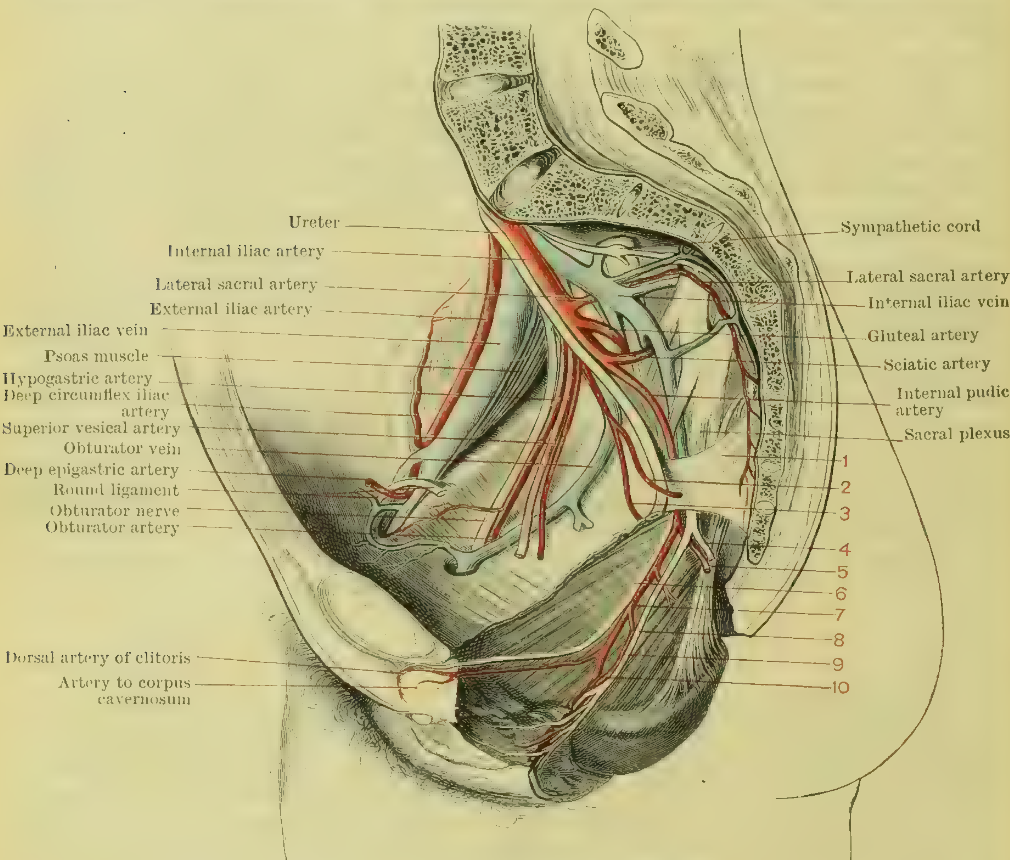


Fig. 569.—The Internal Iliac Artery and its Branches in the Female.

1. Great sacro-sciatic ligament.
2. Uterine artery
3. Vaginal artery.
4. Inferior hæmorrhoidal nerve.
5. Inferior hæmorrhoidal artery.
6. Dorsal nerve of clitoris.
7. Internal pudic artery.
8. Perineal nerve.
9. Superficial perineal artery.
10. Artery to bulb.

above, whilst below this is the obturator nerve, embedded in a mass of fat which intervenes between the internal iliac artery and the side wall of the pelvis. On its inner side it is crossed by some of the tributaries of the internal iliac vein, and is covered by peritoneum.

Branches.—The internal iliac artery supplies the greater part of the pelvic wall and viscera, and its branches are also distributed to the buttock and thigh and to the external organs of generation.

All the branches may be given off separately from a single undivided parent trunk, but as a rule they arise in two groups corresponding to the two divisions in which the artery under these circumstances appears to end.

Posterior division	**parietal**	Ilio-lumbar Lateral sacral Gluteal
Anterior division	**parietal**	Obturator Sciatic Internal pudic
	visceral	Superior vesical (Obliterated hypogastric) Middle vesical Inferior vesical Middle hæmorrhoidal

In the female the inferior vesical is replaced by a vaginal branch, and an additional uterine branch is given off.

Branches of the Posterior Division.

The posterior terminal division gives off the ilio-lumbar and lateral sacral arteries, and is continued as the gluteal artery. No visceral branches are derived from this division.

1. **Ilio-lumbar Artery** (a. ilio-lumbalis).—This vessel runs upwards and outwards across the brim of the pelvis to the iliac fossa. It passes in front of the sacro-iliac articulation, between the lumbo-sacral cord and the obturator nerve, and behind either the lower part of the common or the upper part of the external iliac vessels and the psoas and iliacus muscles.

In the iliac fossa it anastomoses with branches of the deep circumflex iliac and obturator arteries. It also gives offsets to the iliacus, and supplies a large nutrient branch to the ilium. A **lumbar branch** (ramus lumbalis) ascends beneath the psoas to the crest of the ilium. It supplies the psoas and quadratus lumborum, and anastomoses with the lumbar and deep circumflex iliac arteries; it also gives off a *spinal branch* which enters the intervertebral foramen between the fifth lumbar vertebra and the sacrum, and is distributed like the spinal branches of the lumbar and aortic intercostal arteries.

2. **Lateral Sacral Arteries** (aa. sacrales laterales).—There is sometimes only a single lateral sacral artery on each side; more commonly there are two, superior and inferior.

Both branches run downwards and inwards on the front of the sacrum. The inferior passes in front of the pyriformis and the sacral nerves, and descends on the outer side of the sympathetic cord to the coccyx where it terminates by anastomosing with the middle sacral. The superior branch only reaches as far as the first or the second anterior sacral foramen, and then it enters the sacral canal. It anastomoses with the lower branch and with the middle sacral artery. Transverse branches are given off by the lateral sacral arteries to the pyriformis, and to the sacral nerves. Spinal offsets are also given off, which pass through the anterior sacral foramina to the sacral canal; they supply the membranes of the cord, the roots of the sacral nerves, and the filum terminale, and anastomose with other spinal arteries. They then pass backwards through the posterior sacral foramina, and anastomose on the back of the sacrum with branches of the gluteal and sciatic arteries.

3. **Gluteal Artery** (a. glutæa superior, Figs. 569 and 575).—After giving off the ilio-lumbar and lateral sacral branches, the posterior division of the internal iliac is continued as the gluteal artery. This is a large vessel which pierces the pelvic fascia, passes backwards between the lumbo-sacral cord and the first sacral nerve, and leaves the pelvis through the upper part of the great sciatic foramen. It runs above the pyriformis muscle to the buttock, immediately on reaching which it terminates, between the adjacent borders of the pyriformis and gluteus medius muscles and beneath the gluteus maximus, by dividing into superficial and deep branches.

(*a*) The **superficial branch** divides at once into numerous branches, some of which supply

the gluteus maximus, whilst others pass through it, near its origin, to the overlying skin. The branches freely anastomose with branches of the sciatic, internal pudic, internal circumflex, deep circumflex iliac, and lateral sacral arteries.

(*b*) The **deep terminal branch**, accompanied by the superior gluteal nerve, runs forwards between the gluteus medius and minimus, and, after giving a nutrient branch to the ilium, immediately subdivides into upper and lower branches. The *upper branch*, running forwards along the origin of the gluteus minimus from the middle curved line of the ilium, passes beyond the anterior margins of the gluteus medius and minimus to anastomose, under cover of the tensor fascia femoris, with the ascending branch of the external circumflex artery. It also anastomoses with the circumflex iliac artery, and it supplies muscular branches to the adjacent muscles. The *lower branch* passes more directly forwards, across the gluteus minimus, towards the trochanter major, along with the branch of the superior gluteal nerve which supplies the tensor fasciæ femoris. It supplies the glutei muscles, and anastomoses with the ascending branch of the external circumflex artery.

Before leaving the pelvis the gluteal artery gives **muscular branches** to the pelvic diaphragm and the obturator internus, small **neural branches** to the roots of the sacral plexus, and **nutrient branches** to the hip-bone.

Branches of the Anterior Division of the Internal Iliac Artery.

The anterior division gives off both parietal and visceral branches, and is continued as the hypogastric artery, which for the greater part of its extent is obliterated. The parietal branches are the obturator, the pudic, and the sciatic. The visceral branches include the superior, middle and inferior vesical, and the middle hæmorrhoidal arteries in the male. Similar visceral branches are also given off in the female, but the inferior vesical is replaced by the vaginal artery, and an additional branch, the uterine artery, is also given off.

Visceral Branches.

1. The **superior vesical artery** (a. vesicalis superior) arises from the anterior division of the internal iliac. It divides into numerous branches which supply the upper part of the bladder, anastomosing with the other vesical arteries, and it also gives small branches to the urachus, and often to the lower part of the ureter. It may in addition give off the middle vesical artery, and not unfrequently the long slender artery to the vas deferens arises from one of its branches.

2. **Obliterated Hypogastric Artery.**—Atrophy of that portion of the internal iliac artery, which extends from the side of the bladder to the umbilicus (a. umbilicalis), has already been referred to. It is complete between the umbilicus and the true origin of the superior vesical artery, but between this origin and the apparent ending of the internal iliac in its two divisions the atrophy is incomplete, and the lumen of the vessel, though greatly diminished in size, remains, and is looked upon as the first part of the superior vesical artery. Strictly speaking, the first of these two parts only constitutes the "obliterated hypogastric" (ligamentum umbilicale laterale). It is a fibrous cord which runs forwards and upwards towards the apex of the bladder, whence it ascends on the posterior surface of the anterior abdominal wall and on the outer side of the urachus to the umbilicus. As it passes along the wall of the pelvis it is under cover of the peritoneum, and it is crossed by the vas deferens in the male, and by the round ligament in the female.

3. The **middle vesical artery** is usually given off behind the superior vesical. It is distributed to the posterior surface of the bladder as low down as the base; and to the vesiculæ seminales.

4. The **inferior vesical artery** (a. vesicalis inferior) is a very constant branch which runs inwards upon the upper surface of the levator ani to the base of the bladder. It also gives branches to the seminal vesicles, the vas deferens, the lower part of the ureter and the prostate, and it anastomoses with its fellow of the opposite side, with the other vesical arteries, and with the middle hæmorrhoidal artery.

The **artery to the vas** (a. deferentialis), which not unfrequently arises from the superior vesical, is a long slender vessel which runs downwards to the vas and vesicula seminales, and is then continued with the vas deferens to the testicle, where it anastomoses with the spermatic artery. It also anastomoses with the cremasteric branch of the deep epigastric artery.

5. The **middle hæmorrhoidal artery** (a. hæmorrhoidalis media) is an irregular branch which arises either directly from the anterior division of the internal iliac or from the inferior vesical branch; more rarely it springs from the internal pudic artery. It runs inwards, and is distributed to the muscular coats of the rectum; it also gives branches to the prostate, the seminal vesicle, and the vas deferens, and it anastomoses with its fellow of the opposite side, with the inferior vesical, and with the superior and inferior hæmorrhoidal arteries.

6. The **vaginal artery** (a. vaginalis) in the female usually corresponds to the inferior vesical in the male; in which case it arises from the anterior division of the internal iliac, either independently or in common with the uterine artery. Occasionally both inferior vesical and uterine vessels are present, and not uncommonly the vaginal artery is represented by several branches.

The vaginal arteries run downwards and inwards on the floor of the pelvis to the sides of the vagina, and divide into numerous branches which ramify on its anterior and posterior walls. The corresponding branches of opposite sides anastomose and form anterior and posterior longitudinal vessels, the so-called azygos arteries. They also anastomose above with the cervical branches of the uterine artery, and below with the perineal branches of the internal pudic. In addition to supplying the vagina, small branches are given to the bulb of the vestibule, to the base of the bladder, and to the rectum.

7. The **uterine artery** (a. uterina) arises from the anterior division of the internal iliac, either separately or in common with the vaginal or middle hæmorrhoidal arteries. It runs inwards and slightly forwards, upon the upper surface of the levator ani, to the lower border of the broad ligament, between the two layers of which it passes inwards, and arches above the ureter about three quarters of an inch from the uterus. It passes above the lateral fornix of the vagina to the side of the neck of the uterus, and is then directed upwards, until it almost reaches the fundus, just below which, however, it turns outwards beneath the isthmus of the Fallopian tube and anastomoses with the ovarian artery. It supplies the uterus, the upper part of the vagina, the inner part of the Fallopian tube, and gives branches to the round ligament of the uterus. It anastomoses with its fellow of the opposite side, and with the vaginal, the ovarian, and the deep epigastric arteries.

Parietal Branches of the Anterior Division of the Internal Iliac.

1. The **obturator artery** (a. obturatoria, Figs. 569 and 572) runs forwards and downwards along the lateral wall of the true pelvis, just below its brim, to the obturator foramen, through the upper part of which it passes. It terminates immediately on entering the thigh by dividing into internal and external terminal branches which skirt round the margin of the obturator foramen beneath the obturator externus muscle. It is accompanied in the whole of its course by the obturator nerve and vein, the former being above it and the latter below.

To its outer side is the pelvic fascia, which intervenes between it and the upper part of the obturator internus muscle, whilst on its inner side it is covered by peritoneum; between the peritoneum and the artery is the ureter. When the bladder is distended it also comes into close relation with the anterior part of the artery. In the female the ovarian vessels and the broad ligament are on the inner side of the obturator artery.

Branches.—All the branches except the terminal are given off before the artery leaves the pelvis. They include:—(*a*) **Muscular branches** to the obturator internus levator ani and ilio-psoas muscles. (*b*) A **nutrient branch** to the ilium, which passes beneath the ilio-psoas muscle, supplies the bone, and anastomoses with the ilio-lumbar artery. (*c*) A **vesical branch**, or branches, pass inwards to the bladder beneath the

lateral false ligament. (*d*) A **pubic branch** (ramus pubicus), which ascends on the back of the pubes, and anastomoses with its fellow of the opposite side and with the pubic branch of the deep epigastric, is given off just before the artery leaves the pelvis. In its upward course it may pass either on the outer or inner side of the external iliac vein, whilst not unfrequently it runs on the inner side of the crural ring. In the latter case it is important in relation to femoral hernia; and this importance is emphasised when, as sometimes happens, the obturator artery arises as an enlarged pubic branch of the deep epigastric artery instead of from the internal iliac. (*e*) **Terminal.**—The *internal terminal branch* (ramus anterior) runs forwards, and the *external* (ramus posterior) backwards round the margin of the obturator foramen. They lie on the obturator membrane, and under cover of the obturator externus. They anastomose together at the lower margin of the foramen, and both give off offsets which anastomose with the internal circumflex artery, and twigs of supply to the adjacent muscles. The external branch also gives an acetabular branch to the hip-joint, which passes upwards, through

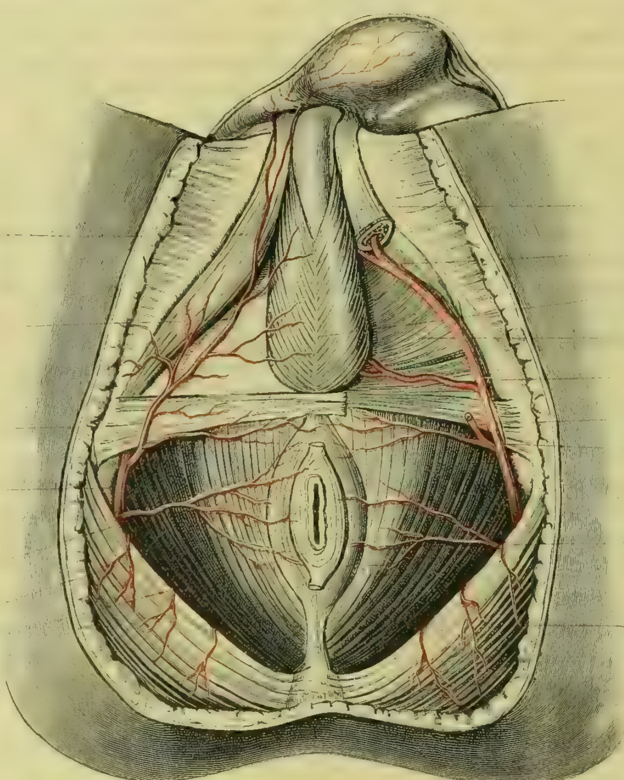


FIG. 570.—THE PERINEAL DISTRIBUTION OF THE INTERNAL PUDIC ARTERY IN THE MALE.

the cotyloid notch on the inner side of the transverse ligament, to supply the ligamentum teres and the head of the femur.

2. **Internal Pudic Artery** (a. pudenda interna, Figs. 569 and 570).—The internal pudic artery arises from the anterior division of the internal iliac close to the origin of the sciatic artery, which slightly exceeds it in size. It runs downwards and backwards in front of the pyriformis muscle and the sacral plexus, from both of which it is separated by the pelvic fascia, and on the outer side of the rectum to the lower part of the great sciatic foramen. In this course it pierces the pelvic fascia, passes between the pyriformis and coccygeus muscles, and leaves the pelvis to enter the buttock in company with the corresponding veins, the sciatic vessels and nerves, the pudic nerve, and the nerve to the obturator internus. In the buttock it lies, under cover of the gluteus maximus, on the spine of the ischium, between the pudic nerve and the nerve to the obturator internus, the former being internal to it. It next passes through the small sciatic foramen and enters the perineum, in the anterior part of which it terminates by dividing into the artery of the corpus cavernosum and the dorsal artery of the penis.

In the first part of its course in the perineum the artery lies in the outer fascial wall of the ischio-rectal fossa, where it is enclosed in the space known as Alcock's canal. This, which is situated about one and a half inches above the lower margin of the tuberosity of the ischium, contains also the pudic veins and the terminal parts of the pudic nerve, viz. the dorsal nerve of the penis which lies above the artery, and the perineal division which lies below the vessel. From the ischio-rectal fossa the internal pudic is continued forwards between the two layers of the triangular ligament of the urethra, and close to the ramus of the pubis. About half-an-inch below the sub-pubic ligament it turns somewhat abruptly forwards, pierces the anterior layer of the triangular ligament, and immediately divides into its terminal branches, viz. the artery of the corpus cavernosum and the dorsal artery of the penis. The division sometimes takes place whilst the artery is still between the layers of the triangular ligament.

Branches.—*In the pelvis* it gives small branches to the neighbouring muscles and to the roots of the sacral plexus.

In the buttock.—(*a*) **Muscular branches** are given to the adjacent muscles. (*b*) **Anastomotic branches** unite with branches of the gluteal sciatic and internal circumflex arteries.

In the ischio-rectal fossa.—(*c*) The **inferior hæmorrhoidal artery** (a. hæmorrhoidalis inferior) pierces the inner wall of Alcock's canal, and runs obliquely forwards and inwards. It soon divides into two or three main branches, which, sometimes arising separately, pass across the space to the lower part of the rectum. The artery anastomoses in the walls of the rectum with its fellow of the opposite side, and with the middle and superior hæmorrhoidal arteries; it also anastomoses with the transverse perineal arteries, and it supplies cutaneous twigs to the region of the anus, and others which turn round the lower border of the gluteus maximus to supply the lower part of the buttock.

(*d*) The **superficial perineal artery** (a. perinei) arises in the anterior part of the ischio-rectal fossa, pierces the base of the triangular ligament, and divides into long slender branches (aa. scrotales posteriores in the male, labiales posteriores in the female) which are continued forwards in the urethral triangle, beneath the superficial perineal fascia, to the scrotum. It anastomoses with its fellow of the opposite side, with the transverse perineal and the external pudic arteries, and it supplies the muscles and subcutaneous structures of the urethral triangle.

(*e*) The **transverse perineal artery** is a small branch which arises either from the internal pudic or from its superficial perineal branch. It runs inwards along the base of the triangular ligament to the central point of the perineum, where it anastomoses with its fellow of the opposite side, with the superficial perineal branch, and with the inferior hæmorrhoidal arteries. It supplies the sphincter ani, the bulbo-cavernosus or sphincter vaginæ, and the anterior fibres of the levator ani.

In the urethral triangle.—(*f*) The **artery to the bulb** (a. bulbi urethræ), a branch which is usually of relatively large size, is given off between the layers of the triangular ligament. It runs transversely inwards along the posterior border of the compressor urethræ, and then turning forwards a short distance from the outer side of the urethra, it pierces the anterior layer of the triangular ligament and enters the substance of the bulb. It passes onwards in the corpus spongiosum to the glans, where it anastomoses with its fellow and with the dorsal arteries of the penis.

It supplies the compressor urethræ muscle, Cowper's gland, the corpus spongiosum, and the penile part of the urethra. In the female this artery supplies the bulb of the vestibule.

(*g*) The **artery of the corpus cavernosum** (a. profunda penis in the male; a. profunda clitoridis in the female) is usually the larger of the two terminal branches. Immediately after its origin it enters the crus penis, and runs forwards in the corpus cavernosum, which it supplies.

(*h*) The **dorsal artery of the penis** (a. dorsalis penis in the male; a. dorsalis clitoridis in the female) passes forwards between the layers of the suspensory ligament, and runs along the dorsal surface of the penis with the dorsal nerve immediately to its outer side, whilst it is separated from its fellow of the opposite side by the single dorsal vein. It supplies the superficial tissues on the dorsal aspect of the penis, sends branches into the corpus cavernosum to anastomose with the artery to the corpus cavernosum, and its terminal branches enter the glans penis, where they anastomose with the arteries to the bulb. It also anastomoses with the external pudic branches of the femoral.

3. **Sciatic Artery** (a. glutæa inferior, Figs. 569 and 571).—The sciatic artery arises, usually distinct from the pudic artery, but sometimes in common with it, from the anterior division of the internal iliac. It descends a little behind and external to the pudic vessels, pierces the pelvic fascia, runs backwards between the first and second, or second and third sacral nerves, and passing between the pyriformis and coccygeus muscles, leaves the pelvis through the lower part of the great sciatic foramen, and enters the buttock just below the pyriformis. In the buttock it descends behind and to the inner side of the great sciatic nerve beneath the gluteus maximus, and over the obturator internus, the two gemelli, the quadratus femoris, and upper part of the adductor magnus muscles, to the upper part of the thigh.

Below the lower border of the gluteus maximus the artery is comparatively superficial, and having given off its largest branches, it descends as a long slender vessel with the small sciatic nerve.

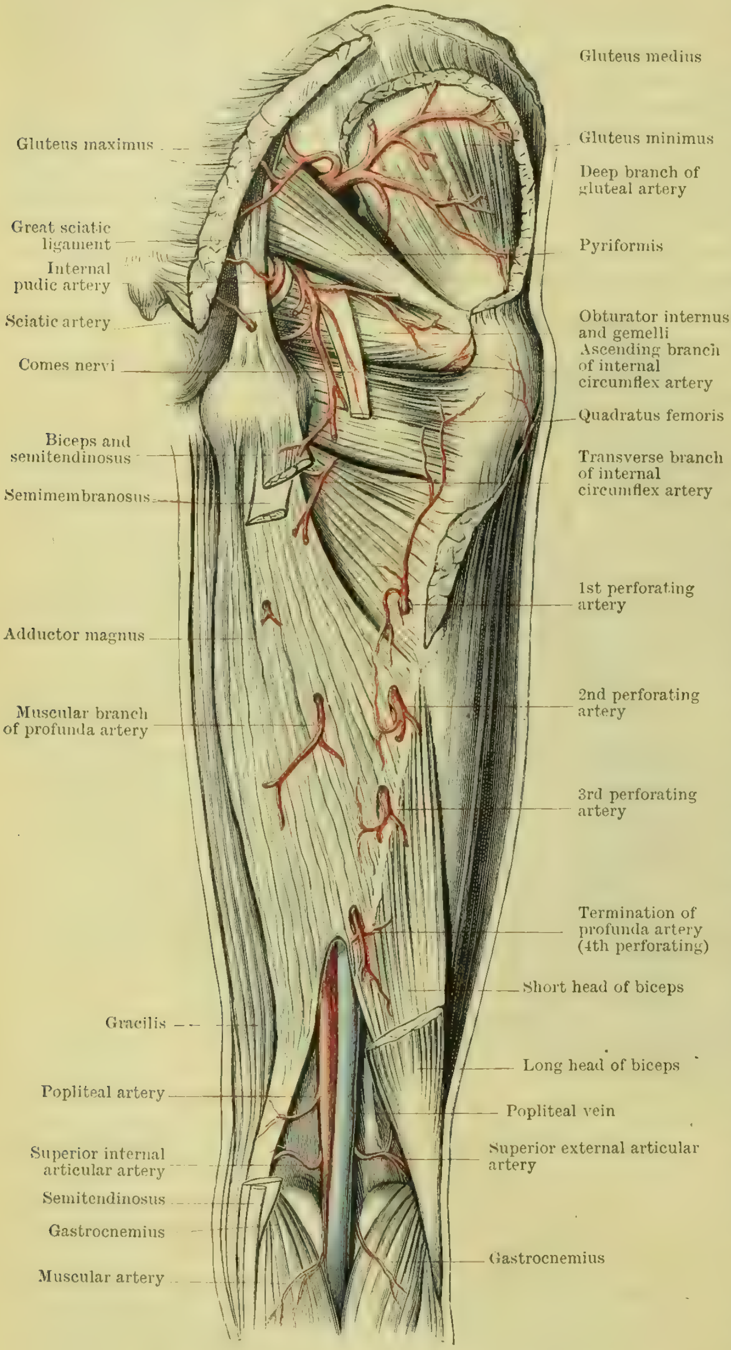


Fig. 571.—The Arteries of the Buttock and the Back of the Thigh and Knee.

Branches.—*In the pelvis.*—Small and irregular branches supply the adjacent viscera and muscles and the sacral nerves; they anastomose with branches of the internal pudic and lateral sacral arteries.

In the buttock.—(*a*) **Muscular branches** are given off to the muscles of the buttock and to the upper parts of the hamstring muscles. They anastomose with the pudic, internal circumflex, and obturator arteries. (*b*) The **coccygeal branch** arises immediately after the artery leaves the pelvis. It runs inwards, pierces the great sacro-sciatic ligament and the gluteus maximus, and ends in the soft tissues over the

back of the lower part of the sacrum and of the coccyx. It gives several branches to the gluteus maximus, and anastomoses with branches of the gluteal and lateral sacral arteries. (*c*) An **anastomotic branch** passes transversely outwards, over or under the great sciatic nerve, towards the great trochanter of the femur. It anastomoses with branches of the gluteal, pudic, internal and external circumflex, and the first perforating arteries, taking part in the formation of the so-called "crucial anastomosis." (*d*) **Cutaneous branches**, accompanying twigs of the small sciatic nerve, pass round the lower border of the gluteus maximus muscle to the integument. (*e*) The **comes nervi ischiatici** (a. comitans n. ischiadici) is a long slender branch which runs down on the surface, or in the substance of the great sciatic nerve. It supplies the nerve, and anastomoses with the perforating arteries and with the termination of the profunda.

ARTERIES OF THE LOWER EXTREMITY.

The main artery of each lower limb is continued from the corresponding common iliac artery. It descends as a single trunk as far as the lower border of the popliteus, and ends there by dividing into the anterior and posterior tibial arteries. Distinctive names are, however, applied to different parts of the artery, corresponding to the several regions through which it passes. Thus in the abdomen it is called the **external iliac artery**, in the upper two-thirds of the thigh it receives the name of the **femoral artery**, whilst its lower part, which is situated on the flexor aspect of the knee, is termed the **popliteal artery**.

THE EXTERNAL ILIAC ARTERY.

The **external iliac artery** (a. iliaca externa) extends from the level of the lumbosacral articulation to a point beneath Poupart's ligament, midway between the anterior superior spine of the ilium and the symphysis pubis, where it becomes the femoral artery. Its length is about three and a half inches (87 to 100 mm.), and in the adult it is usually somewhat larger than the internal iliac artery.

It runs downwards, outwards, and forwards along the brim of the pelvis, resting upon the iliac fascia, which separates it above from the inner border, and below from the anterior surface of the psoas muscle, and it is enclosed with its accompanying vein in a thin fascial sheath.

Relations.—*Anterior.*—It is covered in front by peritoneum, which separates it on the right side from the pelvic colon, iliac colon, and coils of small intestine, and on the right side from the terminal portion of the ileum, and sometimes from the vermiform appendix. The ureter, descending behind the peritoneum, sometimes crosses the front of the artery near its origin, and in the female the ovarian vessels cross the upper part of the artery. Near its lower end the artery is crossed anteriorly by the genital branch of the genito-crural nerve and by the deep circumflex iliac vein. In the male this part of the artery is also crossed by the vas deferens, and in the female by the round ligament of the uterus. Several iliac lymphatic glands lie in front of the external iliac artery, and almost invariably one of these is directly in front of its termination.

Posterior.—The iliac fascia and psoas muscle lie behind the artery. Near its upper end the obturator nerve is also posterior to the vessel.

Lateral.—Externally is the genito-crural nerve; internally, and on a somewhat posterior plane, is the external iliac vein.

Branches.—In addition to small branches to the psoas muscle and to the lymphatic glands, two named branches of considerable size spring from the external iliac artery, viz. the deep epigastric and the deep circumflex iliac.

(1) The **deep epigastric artery** (a. epigastrica inferior, Figs. 569 and 572) arises immediately above Poupart's ligament from the front of the external iliac. Curving forward from its origin it lies in the extra-peritoneal fat, turns round the lower border of the peritoneal sac, and runs upwards and inwards along the inner side of the internal abdominal ring and along the outer border of Hesselbach's triangle; it then pierces the transversalis fascia, passes over the semilunar fold of Douglas and enters the sheath of the rectus abdominis. For a short distance it ascends behind the rectus, but it soon penetrates the substance of the muscle, and breaks up into

branches which anastomose with terminal offsets of the superior epigastric branch of the internal mammary artery and with the lower intercostal arteries. At the internal abdominal ring in the male the vas deferens, the spermatic vessels, and the genital branch of the genito-crural nerve hook round the front and outer side of

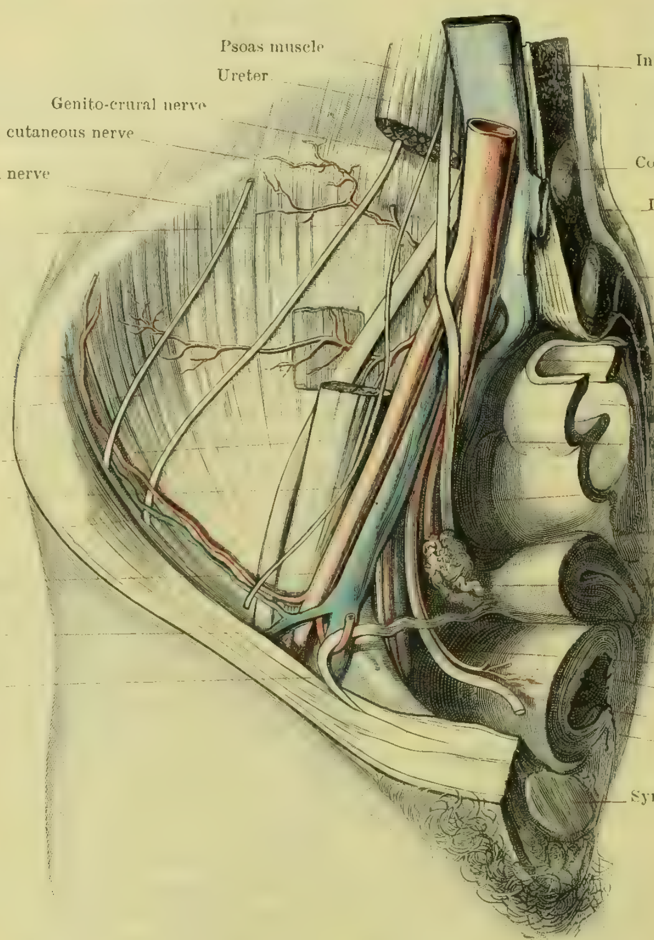


FIG. 572.—THE ILIAC ARTERIES AND VEINS IN THE FEMALE.

the artery, the vas deferens turning inwards behind it; whilst in the female the round ligament of the uterus and the genital branch of the genito-crural nerve occupy the corresponding positions.

Branches.—(*a*) **Muscular branches** which spring mainly from the outer side of the artery supply the rectus, the pyramidalis, the transversalis, and the oblique muscles of the abdominal wall, and they anastomose with branches of the deep circumflex iliac, the lumbar, and the lower intercostal arteries. (*b*) **Cutaneous branches** which pass from the front of the deep epigastric pierce the rectus abdominis and the front part of its sheath, and terminate in the subcutaneous tissues of the anterior abdominal wall, where they anastomose with corresponding branches of the opposite side and with branches of the superficial epigastric artery. (*c*) The **cremasteric branch** (a. spermatica externa in the male, a. ligamenti teretis uteri in the female) is small. It descends through the inguinal canal and anastomoses with the external pudic and superficial perineal arteries, and in the male with the spermatic artery also. In the male it accompanies the spermatic cord, supplying its coverings, including the cremaster. In the female it runs with the round ligament. (*d*) The **pubic branch** (ramus pubicus) descends either on the outer or the inner side of the crural ring to anastomose with the pubic branch of the obturator artery; it also anastomoses with its fellow of the opposite side. Sometimes when the obturator branch of the internal iliac artery is absent, the pubic branch of the deep epigastric artery enlarges and becomes the obturator artery, which descends to the obturator foramen

either on the outer or the inner side of the crural ring. In the latter case the artery may be injured in the operation for the relief of a strangulated femoral hernia.

(2) The **deep circumflex iliac artery** (a. circumflexa ilium profunda, Figs. 569 and 572) springs from the outer side of the external iliac artery, usually a little below the deep epigastric, and immediately above Poupart's ligament. It runs outwards and upwards to the anterior superior spine of the ilium. In this part of its course it lies just above the lower border of Poupart's ligament, and is enclosed in a fibrous canal formed by the union of the transversalis and iliac fasciæ. Opposite the anterior superior spine it pierces the transversalis abdominis, and is continued backwards between the transversalis and the internal oblique, to terminate by anastomosing with branches of the ilio-lumbar artery.

Branches. — (*a*) **Muscular** to the upper parts of the sartorius and the tensor fasciæ femoris, and to the muscles of the abdominal wall. One of the latter branches is frequently of considerable size; it pierces the transversalis muscle a short distance in front of the anterior superior spine of the ilium, and ascends vertically between the transversalis and the internal oblique, anastomosing with the lumbar and epigastric arteries. (*b*) **Cutaneous branches** pierce the internal and external oblique muscles. They terminate in the skin over the crest of the ilium, and they anastomose with the gluteal, the superficial circumflex iliac and the ilio-lumbar arteries.

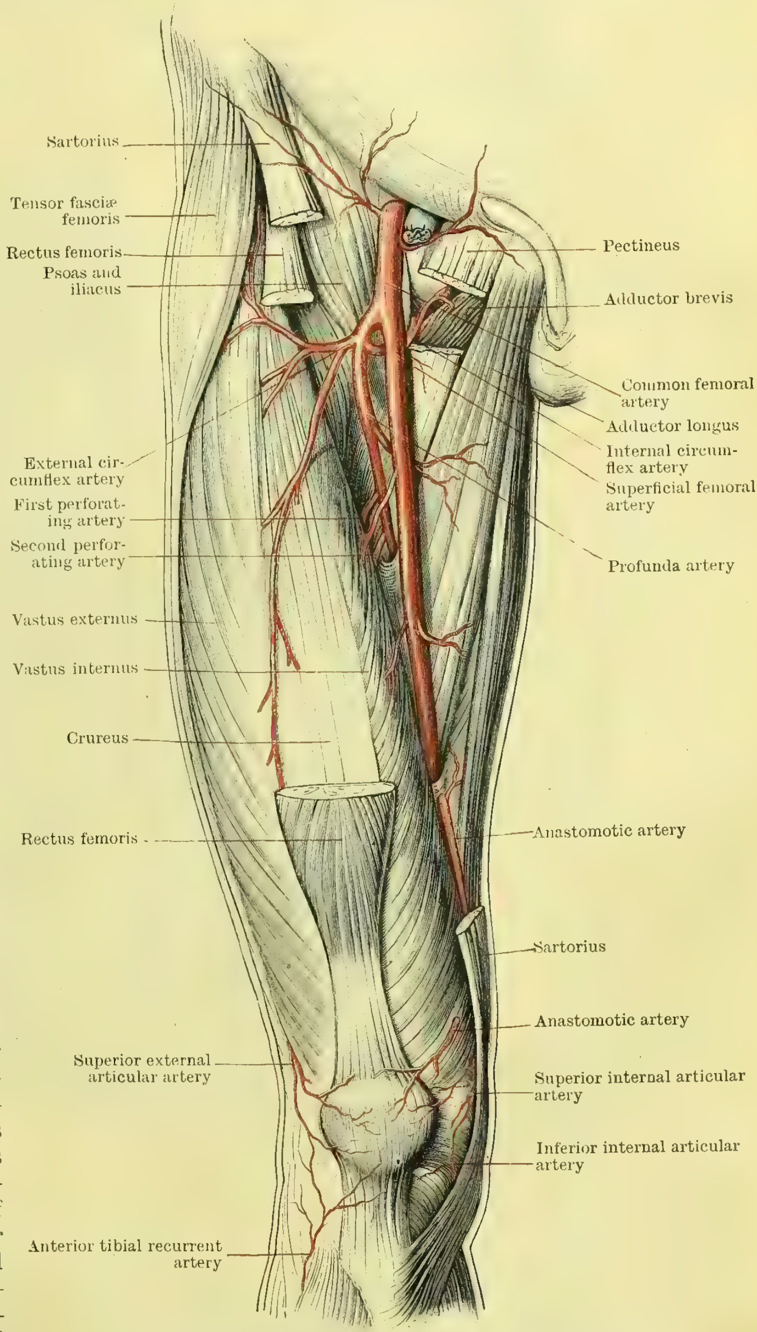


Fig. 573.—The Femoral Artery and its Branches

THE FEMORAL ARTERY.

The **femoral artery** (a. femoralis, Figs. 573 and 574) continues the external iliac into the thigh. It commences at the lower border of Poupart's ligament, and, descending through the upper two-thirds of the thigh, terminates at the opening in the adductor magnus.

Course.—Its general direction is indicated by a line drawn from the point of origin midway between the anterior superior spine of the ilium and the symphysis pubis to the adductor tubercle, the thigh being flexed and rotated outwards.

In its upper half the femoral artery lies in Scarpa's triangle, and is comparatively superficial; at the apex of the triangle it passes beneath the sartorius, enters Hunter's canal, and is thus more deeply placed.

At its entry into Scarpa's triangle both the artery and its vein are enclosed, for a distance of one and a quarter inches, in a funnel-shaped fascial sheath formed of the fascia transversalis in front and the iliac fascia behind. This is called the **femoral sheath**; it is divided by septa, running from front to back, into three compartments, the outer of which is occupied by the femoral artery and genito-crural nerve. The middle contains the femoral vein, and the internal compartment constitutes the crural canal.

Relations.—In *Scarpa's triangle* the femoral artery is covered by skin and fascia, by superficial inguinal lymphatic glands and small superficial vessels. The anterior part of the femoral sheath and the cribriform fascia are in front of the upper part of the artery, and the fascia lata is in front of the lower part. Near the apex of the triangle the artery is crossed by the internal cutaneous nerve, and not infrequently by a tributary of the internal saphenous vein. Behind, it is in relation, from above downwards, with the posterior part of the femoral sheath, the pubic portion of the fascia lata and the psoas, the pectineus, and the upper part of the adductor longus muscles. The nerve to the pectineus passes between the artery and the psoas; the femoral vein and the profunda artery and vein intervene between it and the pectineus, and the femoral vein also separates it from the adductor longus.

The femoral vein which lies behind the artery in the lower part of Scarpa's triangle passes to its inner side above, but is separated from the artery by the outer septum of the femoral sheath. On the outer side of the artery is the anterior crural nerve above; lower down the internal saphenous nerve and the nerve to the vastus internus are continued on the outer side. The crural branch of the genito-crural nerve is in front and to the outer side above, and runs for a short distance in the femoral sheath.

In *Hunter's canal* the artery has behind it the adductor longus and the adductor magnus, whilst in front and to the outer side is the vastus internus. The femoral vein is also behind the artery, but lies to its outer side below and to its inner side above. Superficial to the artery is the fascial roof of the canal, upon which is the sub-sartorial plexus of nerves and the sartorius muscle. The internal or long saphenous nerve enters Hunter's canal with the artery, and runs first on its outer side, then in front, and lastly on its inner side.

Branches.—The femoral artery gives off the following branches:—

(1) Superficial branches.
- (*a*) The superficial external pudic.
- (*b*) The superficial epigastric.
- (*c*) The superficial circumflex iliac.

(2) Muscular.
(3) The deep external pudic.
(4) The profunda.
(5) The anastomotica magna.

(*a*) The **superficial circumflex iliac** (a. circumflexa ilium superficialis) springs from the front of the femoral artery just below Poupart's ligament. It pierces the femoral sheath and the fascia lata, external to the saphenous opening, and runs in the superficial fascia as far as the anterior superior spine of the ilium. It supplies the outer set of inguinal glands and the skin of the groin, and it sends branches through the fascia lata which anastomose with the deep circumflex iliac and supply the upper parts of the sartorius and tensor fasciæ femoris muscles.

(*b*) The **superficial epigastric artery** (a. epigastrica superficialis) arises near

the preceding. It pierces the femoral sheath and the cribriform fascia, and passes upwards and inwards between the superficial and deep layers of the superficial fascia of the abdominal wall towards the umbilicus. It supplies the inguinal glands and the integument, and anastomoses with its fellow of the opposite side, with the deep epigastric, and with the superficial circumflex iliac and superficial external pudic arteries.

(*c*) The **superficial external pudic artery** (a. pudenda externa superficialis) also springs from the front of the femoral artery, and, after piercing the femoral sheath and the cribriform fascia, runs upwards and inwards towards the

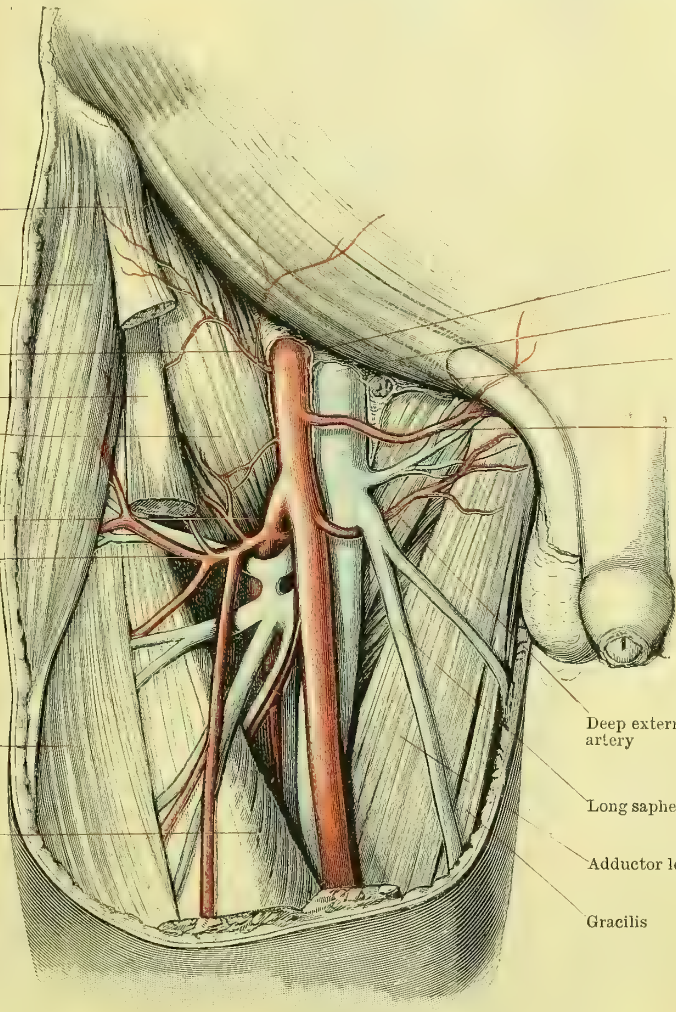


FIG. 574.—THE FEMORAL VESSELS IN SCARPA'S TRIANGLE.

spine of the pubis, where it crosses superficial to the spermatic cord. It supplies the integument of the lower part of the abdominal wall, the root of the dorsum of the penis in the male, and the region of the mons Veneris in the female, and it anastomoses with its fellow of the opposite side, the deep external pudic, the dorsal artery of the penis, and the superficial epigastric arteries.

(2) **Muscular branches** are distributed to the pectineus and the adductor muscles on the inner side, and to the sartorius and the vastus internus on the outer side.

(3) The **deep external pudic artery** (a. pudenda externa profunda) rises from the inner side of the femoral. It runs inwards, across the front of the pectineus, and in front of or behind the adductor longus, to the inner side of the thigh; it then

pierces the deep fascia, and terminates in the scrotum, where it anastomoses with the superficial perineal and superficial external pudic arteries, and with the cremasteric branch of the deep epigastric artery.

(4) The **profunda artery** (a. profunda femoris, Fig. 573) is a large branch only slightly smaller than the continuation of the femoral artery. It arises about an inch and a half below Poupart's ligament, from the outer side of the femoral artery. Curving backwards and inwards, it passes behind the latter vessel, and runs downwards, close to the inner aspect of the femur, to the lower third of the thigh, where it perforates the adductor magnus and passes to the back of the thigh. Its termination is known as the fourth perforating artery. As the profunda descends it lies upon the iliacus, the pectineus, the adductor brevis, and the adductor magnus. It is separated from the femoral artery by its own vein, by the femoral vein, and by the adductor longus muscle behind which it passes.

Branches.—(*a*) **Muscular branches** are given off from the profunda both in Scarpa's triangle, and whilst it lies between the adductor muscles; many of them terminate in the adductors, others pass through the adductor magnus, and terminate in the hamstrings, where they anastomose with the transverse branch of the internal circumflex and with the upper muscular branches of the popliteal artery.

(*b*) The **external circumflex artery** (a. circumflexa femoris lateralis, Figs. 573 and 574) springs from the outer side of the profunda, or occasionally from the femoral artery above the origin of the profunda. It runs outwards across the front of the iliacus, and between the superficial and deep branches of the anterior crural nerve, to the outer border of Scarpa's triangle; then, passing beneath the sartorius and the rectus femoris, it terminates by dividing into three terminal branches—the ascending, the transverse, and the descending. Before its termination it supplies branches to the muscles mentioned and to the upper part of the crureus.

(i.) The **ascending terminal branch** (ramus ascendens) runs upwards and outwards, beneath the rectus femoris and the tensor fasciæ femoris, along the anterior intertrochanteric line, to the anterior borders of the gluteus medius and minimus, between which it passes to anastomose with the deep branches of the gluteal artery. It supplies twigs to the neighbouring muscles, anastomoses with the gluteal, the deep circumflex iliac, and the transverse branch of the external circumflex arteries, and, as it ascends along the anterior intertrochanteric line, gives off a branch which passes between the two limbs of the Y-shaped ligament into the hip-joint. (ii.) The **transverse terminal branch** is small; it runs outwards between the crureus and the rectus femoris, passes into the substance of the vastus externus, winds round the femur, and anastomoses with the ascending and descending branches, with the perforating branches of the profunda, and with the sciatic and internal circumflex arteries. (iii.) The **descending terminal branch** (ramus descendens) runs downwards beneath the rectus and along the anterior border of the vastus externus accompanied by the nerve to the latter muscle. It anastomoses with the transverse branch, with twigs of the inferior perforating arteries, with the anastomotic branch of the femoral, and with the superior external articular branch of the popliteal artery.

(*c*) The **internal circumflex artery** (a. circumflexa femoris medialis, Fig. 573) springs from the inner and back part of the profunda, at the same level as the external circumflex, and runs backwards, through the floor of Scarpa's triangle, passing between the psoas and the pectineus; crossing the upper border of the adductor brevis it is continued backwards beneath the neck of the femur, and passes between the adjacent borders of the obturator externus and the adductor brevis to the upper border of the adductor magnus, where it divides into two terminal branches, a transverse and an ascending.

Branches.—(i.) An **articular branch** (ramus acetabuli) is given off as the artery passes beneath the neck of the femur. It ascends to the cotyloid notch where it anastomoses with twigs from the posterior branch of the obturator artery, and it sends branches into the cotyloid cavity and along the ligamentum teres to the head of the femur. (ii.) **Muscular branches** are given off to the neighbouring muscles. The largest of these branches usually rises immediately before the termination of the artery, it descends on the anterior aspect of the adductor magnus and anastomoses with the muscular branches of the profunda artery. (iii.) The **ascending terminal branch** (ramus profundus) passes upwards and outwards, between the obturator externus and the quadratus femoris to the digital fossa of the femur, where it anastomoses with branches of the gluteal and the sciatic arteries. (iv.) The **transverse terminal branch** (ramus superficialis) runs backwards between the lower border of the quadratus femoris and the upper border of the adductor magnus to the hamstring muscles. It anastomoses under the lower part of the gluteus maximus with the sciatic and first perforating arteries and with the transverse branch of the external circumflex, and in the substance of the hamstrings with the muscular branches of the profunda.

(*d*) The **perforating arteries** (Fig. 575), including the terminal branch of the profunda, are four in number. They curve backwards and outwards round the posterior aspect of the femur, lying close to the bone, under well-marked tendinous arches, which interrupt the continuity of muscular attachments; their terminal branches enter the vastus externus and anastomose in its substance with each other, with the descending branch of the external circumflex, with the anastomotic, and with the superior external articular branch of the popliteal.

The **first perforating artery** (a. perforans prima) pierces the insertions of the adductors brevis and magnus, and some of its branches anastomose beneath the gluteus maximus with the sciatic, with the transverse branch of the internal circumflex, and with the transverse branch of the external circumflex, forming what is known as the crucial anastomosis.

The **second perforating artery** (a. perforans secunda) pierces the adductors brevis and magnus, and then passes between the gluteus maximus and the short head of the biceps into the vastus externus. It anastomoses with its fellows above and below, and with the internal circumflex and the upper muscular branches of the popliteal artery.

The **third** (a. perforans tertia) and **fourth perforating arteries** pass through the adductor magnus and the short head of the biceps into the vastus externus. Their anastomoses are similar to those of the second perforating.

A **nutrient branch** (a. nutricia femoris) to the femur is given off either from the second or third perforating artery, usually the former; an additional nutrient branch may also be supplied by the first or fourth perforating arteries.

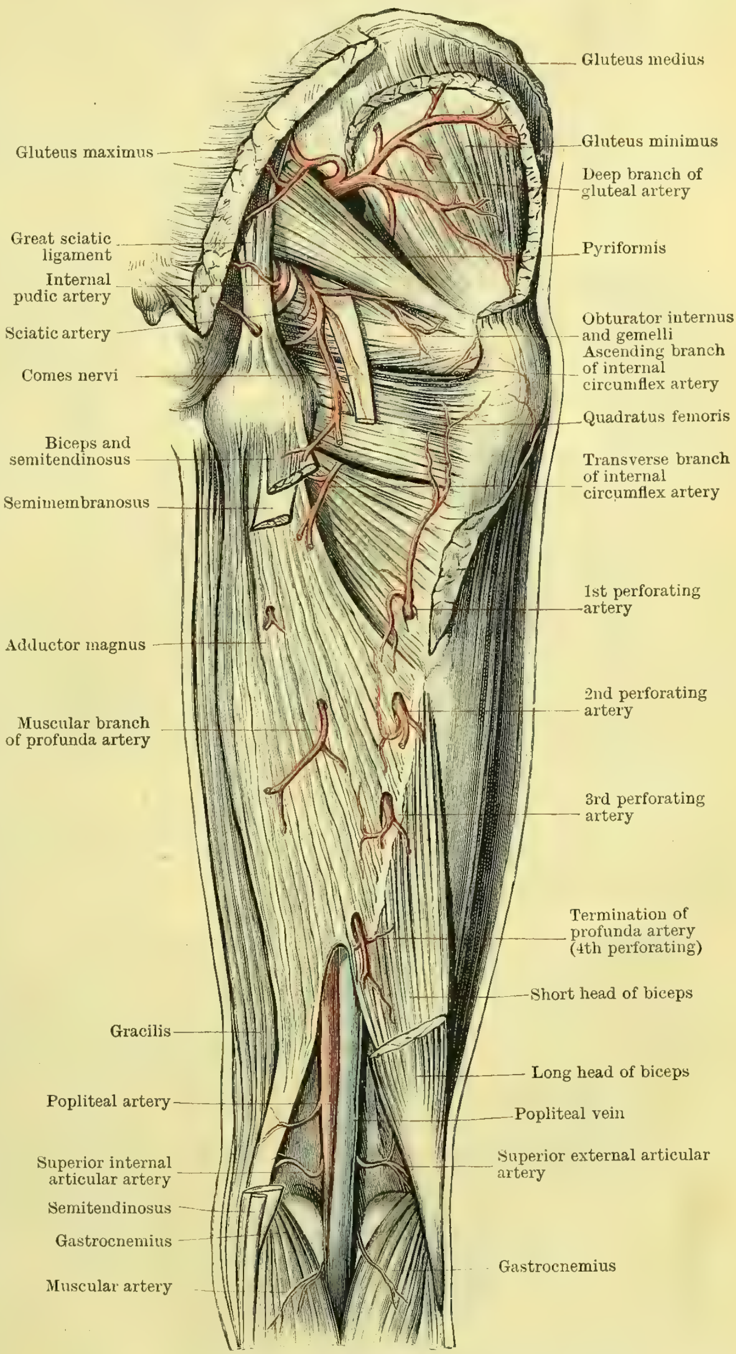


FIG. 575.—THE ARTERIES OF THE BUTTOCK AND THE BACK OF THE THIGH AND KNEE.

(5) The **anastomotic** (a. genu suprema) arises near the termination of the femoral artery in the lower part of Hunter's canal, and divides almost immediately into a superficial and a deep branch; indeed, very frequently the two branches arise separately from the femoral trunk

(*a*) The **superficial branch** (ramus saphenus) passes through the lower end of Hunter's canal with the long saphenous nerve, and appears superficially on the inner side of the knee between the gracilis and the sartorius. It gives twigs to the integument of the upper and inner part of the leg, and it anastomoses with the inferior internal articular artery. (*b*) The **deep branch** (ramus musculo-articularis) descends in the substance of the vastus internus along the anterior aspect of the tendon of the adductor magnus. It anastomoses with the superior internal articular artery, and it sends branches outwards, one on the surface of the femur and another along the upper border of the patella, to anastomose with the descending branch of the external circumflex, the inferior perforating artery, the superior external articular, and the anterior tibial recurrent.

THE POPLITEAL ARTERY.

The **popliteal artery** (a. poplitea) is the direct continuation of the femoral. It commences at the upper and inner part of the popliteal space, under cover of the semimembraneous, and terminates at the lower border of the popliteus muscle, and on a level with the lower part of the tubercle of the tibia, by dividing into the anterior and the posterior tibial arteries.

From its origin the artery descends, with an outward inclination, to the inter-space between the condyles of the femur, whence it is continued vertically downwards to its termination.

Relations.—*Anterior.*—It is in contact in front and from above downwards with the popliteal surface of the femur, the posterior ligament of the knee-joint, and the fascia covering the posterior surface of the popliteus.

Posterior.—The artery is overlapped behind by the outer border of the semimembranosus above; it is crossed about its middle by the popliteal vein and the internal popliteal nerve, the vein intervening between the artery and the nerve; whilst in the lower part of its extent it is overlapped by the adjacent borders of the two heads of the gastrocnemius, and crossed by the nerve to the popliteus and by the plantaris muscle.

Lateral.—On its outer side it is in relation above with the internal popliteal nerve and the popliteal vein, then with the outer condyle of the femur, and below with the outer head of the gastrocnemius and with the plantaris.

On the inner side it is in relation above with the semimembranosus, in the middle with the inner condyle of the femur, and below with the internal popliteal nerve, the popliteal vein, and the internal head of the gastrocnemius. Popliteal lymphatic glands are arranged irregularly around the artery.

Branches.—(1) **Muscular branches** are given off in two sets, upper and lower.

The upper muscular branches are distributed to the lower parts of the hamstring muscles, in which they anastomose with branches of the profunda artery.

The lower muscular, or sural, arteries (aa. surales) enter the upper parts of the gastrocnemius, the plantaris, the soleus, and the popliteus muscles, and they anastomose with branches of the posterior tibial artery and the lower articular arteries.

(2) The **articular branches** are five in number—viz. upper and lower external, upper and lower internal, and an azygos branch.

(*a*) The **superior external articular artery** (a. genu superior lateralis) passes outwards above the external condyle, behind the femur and in front of the biceps tendon, into the vastus externus, where it anastomoses with the anastomotic, the descending branch of the external circumflex, and the lowest perforating artery; it also sends branches downwards to anastomose with the inferior external articular and with the anterior tibial recurrent.

(*b*) The **superior internal articular artery** (a. genu superior medialis) passes inwards above the internal condyle, behind the femur, and in front of the tendon of the adductor magnus, into the vastus internus. It anastomoses with branches of the anastomotic and of the superior external articular artery.

(*c*) The **inferior external articular artery** (a. genu inferior lateralis) runs outwards across the popliteus muscle and in front of the plantaris and the external head of the gastrocnemius; then turning forwards, it is joined by the inferior external articular nerve, and passes to the inner side of the external lateral ligament, where it terminates by anastomosing with its fellow of the opposite side and with the superior external articular and anterior tibial recurrent arteries.

(*d*) The **inferior internal articular artery** (a. genu inferior medialis) passes inwards below the inner tuberosity of the tibia, along the upper border of the popliteus and in front of

the internal head of the gastrocnemius, to the inner side of the knee, where it turns forwards between the bone and the internal lateral ligament, and terminates anteriorly by anastomosing with its fellow of the opposite side, with the recurrent branch of the anterior tibial artery, and with the superior internal articular artery.

(*e*) The **azygos articular artery** (a. genu media) passes directly forwards from the front of the popliteal artery, pierces the central part of the posterior ligament of the knee-joint, and enters the intercondylar space. It supplies branches to the crucial ligaments and to the synovial membrane, and is accompanied by the azygos articular branch of the internal popliteal nerve, and sometimes by the genicular branch of the obturator nerve.

(3) **Cutaneous branches** are distributed to the skin over the popliteal space. One of these, the *superficial sural artery*, descends in the middle line of the back of the calf along with the external saphenous nerve.

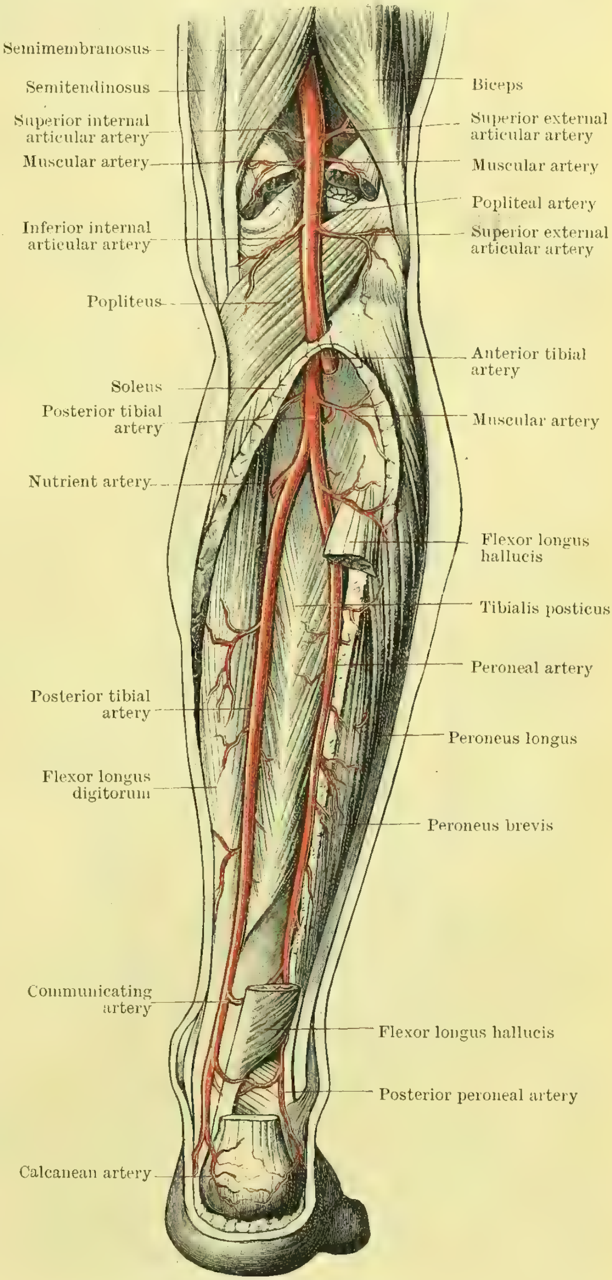


FIG. 576.—THE POPLITEAL AND POSTERIOR TIBIAL ARTERIES AND THEIR BRANCHES.

THE POSTERIOR TIBIAL ARTERY.

The **posterior tibial artery** (a. tibialis posterior), the larger of the two terminal branches of the popliteal, commences at the lower border of the popliteus and terminates midway between the tip of the inner malleolus and the most prominent part of the heel, at the lower border of the internal annular ligament. It ends by dividing into the internal and the external plantar arteries, which pass onwards to the sole of the foot.

The artery runs downwards and inwards on the back of the leg between the superficial and deep layers of muscles, and covered by the deep intermuscular fascia which intervenes between them.

Relations.—*Anterior.*—It is in contact in front, and from above downwards, with the tibialis posticus, the flexor longus digitorum, the posterior surface of the tibia, and the posterior ligament of the ankle-joint.

Posterior.—The artery is crossed about an inch and a-half below its origin by the posterior tibial nerve. Elsewhere it is in contact with the intermuscular fascia, which binds down the deep layer of muscles. More superficially the upper half of the artery is covered by the fleshy parts of the soleus and gastrocnemius muscles, between which is the plantaris; the lower half of the artery is much nearer the surface, and is only covered by

skin and fascia, except at its termination, where it lies beneath the internal annular ligament and the origin of the abductor hallucis.

Lateral.—The artery is accompanied by two venæ comites, one on either side. The posterior tibial nerve lies at first on the inner side of the vessel, then crosses behind it, and is continued down on its outer side. In the last part of its course the artery is separated from the internal malleolus by the tendons of the tibialis posticus and the flexor longus digitorum, whilst the tendon of the flexor longus hallucis lies behind and external to it.

Branches.—The posterior tibial gives off numerous branches, the largest of which, the peroneal, forms one of the chief arteries of the leg. The branches include—

(1) Two large **muscular branches** which are distributed to the soleus, the tibialis posticus, the flexor longus digitorum, and the flexor longus hallucis. They anastomose with the deep sural branches of the popliteal artery and the lower internal articular artery.

(2) The **medullary branch** (a. nutricia tibiæ), the largest of the medullary group of arteries, springs from the upper part of the posterior tibial, pierces the tibialis posticus, and enters the medullary foramen on the posterior surface of the tibia. In the interior of the bone it divides into ascending and descending branches, the former passing upwards towards the head of the bone, and the latter downwards towards the lower extremity. Before entering the tibia the medullary artery gives small muscular branches.

(3) A **communicating branch** (ramus communicans) unites the posterior tibial to the peroneal artery about an inch above the inferior tibio-fibular articulation. It passes behind the shaft of the tibia and in front of the flexor longus hallucis.

(4) **Cutaneous branches** are distributed to the skin of the inner and posterior part of the leg.

(5) An **internal malleolar branch** (a. malleolaris posterior medialis) is distributed to the internal surface of the inner malleolus, anastomosing with a corresponding branch of the anterior tibial artery.

(6) The **peroneal artery** (a. peronæa, Fig. 576) is the largest branch of the posterior tibial. It arises about an inch below the lower border of the popliteus, curves outwards across the upper part of the tibialis posticus to the postero-internal border of the fibula, along which it descends to the lower part of the interosseous space, and it terminates about an inch above the ankle-joint by dividing into anterior and posterior terminal branches.

As the peroneal artery passes outwards from its origin it lies behind the tibialis posticus, and is covered posteriorly by the deep intermuscular fascia and by the soleus. As it descends along the postero-internal border of the fibula it lies in a fibrous canal between the tibialis posticus in front and the flexor longus hallucis behind. The peroneal artery is accompanied by two venæ comites, and is crossed in front and behind by communicating branches between them.

Branches.—(*a*) **Muscular branches** are distributed to the soleus, tibialis posticus, flexor longus hallucis, and peroneal muscles. Some pass through the interosseous membrane and supply the anterior muscles of the leg.

(*b*) A **medullary branch** (a. nutricia fibulæ) enters the medullary foramen of the fibula.

(*c*) A **communicating branch** (a. communicans) passes across the back of the lower end of the shaft of the tibia, about an inch above the inferior tibio-fibular articulation, to anastomose with the posterior tibial artery.

(*d*) The **terminal branches** are: (i.) The anterior terminal branch or *anterior peroneal artery* (ramus perforans), which passes forwards between the lower border of the interosseous membrane and the interosseous inferior tibio-fibular ligament, and runs in front of the ankle to the dorsum of the foot, where it anastomoses with the external malleolar branch of the anterior tibial artery and with the tarsal branch of the dorsalis pedis; it also supplies branches to the inferior tibio-fibular articulation, to the ankle-joint, and to the peroneus tertius.

(ii.) The posterior terminal branch (ramus calcaneus lateralis), or *posterior peroneal artery*, passes downwards behind the inferior tibio-fibular articulation and external malleolus to the outer side of the heel and the foot. It supplies the ankle, the inferior tibio-fibular articulation, and the calcaneo-astragaloid joint, and anastomoses with the internal calcaneal branch of the external plantar artery, and with the tarsal and metatarsal branches of the dorsalis pedis.

Plantar Arteries.

(7) The **internal** and **external plantar arteries** are the terminal branches of the posterior tibial artery. They arise beneath the origin of the abductor hallucis muscle, midway between the tip of the internal malleolus and the most prominent part of the inner side of the os calcis.

Internal Plantar Artery (a. plantaris medialis).—This is the smaller of the two terminal branches of the posterior tibial artery. It passes forwards along the

inner side of the foot, in the interval between the abductor hallucis and the flexor brevis digitorum, to the head of the first metatarsal bone, where it terminates by uniting with the plantar digital branch of the dorsalis hallucis, which is distributed to the inner side of the great toe. In its course forwards it gives branches to the adjacent muscles and articulations, and to the subjacent skin; it also gives three digital branches which anastomose at the roots of the inner three interdigital clefts, with the princeps hallucis branch of the dorsalis pedis and with the inner two digital branches from the plantar arch. Some of the cutaneous branches of the internal plantar artery anastomose, round the inner border of the foot, with the inner cutaneous branches of the dorsalis pedis artery.

External Plantar Artery (a. plantaris lateralis). — This artery, the larger of the two terminal branches of the posterior tibial artery, runs forwards and outwards, first between the flexor brevis digitorum and the accessorius and then in the interval between the flexor brevis digitorum and the abductor minimi digiti, to the inner side of the base of the fifth metatarsal bone, where it turns abruptly inwards; it then passes across the bases of the metatarsal bones and the origins of the interossei, and above the oblique adductor of the great toe, to the outer side of the base of the first metatarsal bone, where it terminates by anastomosing with the dorsalis pedis artery. The last part of the artery is convex forwards and forms the plantar arch, which is completed by the dorsalis pedis.

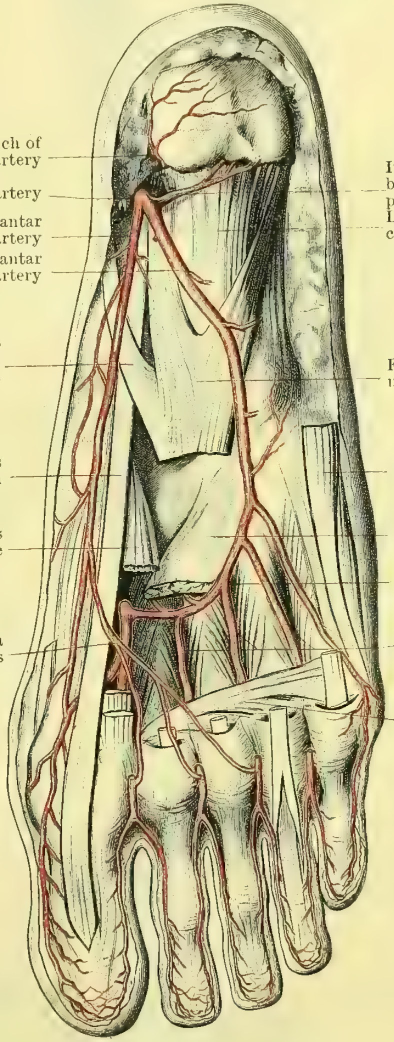


Fig. 577.—The Plantar Arteries and their Branches.

Branches.—Between its origin and the base of the fifth metatarsal the external plantar artery gives off (*a*) the **internal calcaneal branch**, which is distributed to the skin and the subcutaneous tissue of the heel.

(*b*) **Muscular branches** to the abductor hallucis, flexor brevis digitorum, accessorius, and abductor minimi digiti.

(*c*) **Cutaneous branches** to the skin of the outer side of the foot.

Between the base of the fifth metatarsal bone and the first interosseous space it forms the **plantar arch** (arcus plantaris), and gives off (*d*) four **digital branches** (aa. metatarsæ plantares); (*e*) three **posterior perforating arteries** (rami perforantes) to the dorsal interosseous arteries; and (*f*) **articular branches** to the tarsal joints.

The **outermost digital branch** runs along the outer side of the little toe, supplying the skin, joints, and the flexor tendons with their synovial sheaths. The **inner three digital branches** run forwards on the plantar surfaces of the interossei, the inner two lying dorsal to the oblique adductor of the great toe, and all three passing dorsal to the

transverse adductor. At the bases of the interdigital clefts the three inner digital arteries divide into collateral branches (aa. digitales plantares) which run along the plantar aspect of adjacent toes, and supply skin, joints, and the flexor tendons and sheaths. Opposite the last phalanx of each toe the digital arteries anastomose.

The **posterior perforating arteries** are three in number; they pass dorsalwards through the three outer interosseous spaces, between the heads of the dorsal interosseous muscles, and terminate by uniting with the dorsal interosseous branches of the metatarsal artery. **Anterior perforating branches** which communicate with the dorsal interosseous arteries are given off from two or three of the digital arteries just before they divide.

The **articular branches** are numerous and irregular; they supply the joints and ligaments of the tarsus on its plantar aspect.

FIG. 578.—THE ANTERIOR TIBIAL ARTERY AND ITS BRANCHES.

THE ANTERIOR TIBIAL ARTERY.

The **anterior tibial artery** (a. tibialis anterior), the smaller of the two terminal divisions of the popliteal, commences opposite the lower border of the popliteus muscle, and terminates in front of the ankle, where it is continued into the dorsal artery of the foot.

Course and Relations.—From its origin at the back of the leg the artery passes forwards to the front, between the two uppermost slips of the tibialis posticus and above the upper border of the interosseous membrane. It then descends resting, in the upper two-thirds of its course, upon the anterior surface of the interosseous membrane and, subsequently, on the shaft of the tibia and the anterior ligament of the ankle-joint. In the upper third of the anterior compartment of the leg it lies between the extensor longus digitorum externally and the tibialis anticus internally; in the middle third it is between the extensor longus hallucis and the tibialis anticus; in the lower third the extensor proprius hallucis crosses in front of the artery and reaches its inner side, and the last part of the vessel lies

between the tendon of the extensor proprius hallucis and the innermost tendon of the extensor longus digitorum.

The anterior tibial nerve is at first well to the outer side of the artery, but it soon passes in front of the vessel, and it lies upon the artery in its middle third; lower down the nerve is usually found on the outer side again, and at the ankle it intervenes between the artery and the innermost tendon of the extensor longus digitorum.

Two venæ comites, with numerous intercommunications, accompany the artery.

Obviously the anterior tibial artery is, at least in its upper part, deeply placed; moreover, its lateral muscular boundaries overlap it. In the greater part of its extent it is, however, easily accessible from the surface; and beyond being crossed by the nerve and tendon, as already described, is only covered, in addition, by skin, fascia, and the anterior annular ligament.

Branches.—Close to its origin the artery gives off superior fibular and posterior tibial recurrent branches; after it reaches the front of the leg it gives off anterior tibial recurrent, muscular, cutaneous, internal malleolar, and external malleolar branches.

(1) The **superior fibular branch** is a small vessel which may arise separately from the anterior tibial artery, or by a common stem with the posterior tibial recurrent; occasionally it springs from the lower end of the popliteal artery, or from the posterior tibial. It runs upwards and outwards behind the neck of the fibula and through the fibres of the soleus, and it terminates in branches which supply the soleus, the peroneus longus, and the skin of the upper and outer part of the leg. It anastomoses with the inferior external articular artery.

(2) The **posterior tibial recurrent branch** (a. recurrens tibialis posterior), also small, and not always present, runs upwards in front of the popliteus muscle to the back of the knee-joint. It anastomoses with the inferior articular branches of the popliteal, and gives branches to the popliteus muscle and the superior tibio-fibular articulation.

(3) The **anterior tibial recurrent branch** (a. recurrens tibialis anterior) arises from the anterior tibial artery in front of the interosseous membrane. It runs upwards and inwards, between the upper part of the tibialis anticus and the outer tuberosity of the tibia, accompanied by the recurrent articular branch of the external popliteal nerve, and after supplying the tibialis anticus and the superior tibio-fibular articulation it pierces the deep fascia of the leg; it is connected with the anastomoses round the knee-joint formed by the articular branches of the popliteal artery, the descending branch of the external circumflex artery, and the anastomotic artery.

(4) The **muscular branches** are distributed to the muscles of the front of the leg, and a few small branches also pass backwards to the deep surface of the tibialis posticus muscle.

(5) The **cutaneous branches** supply the skin of the front of the leg.

(6) The **internal malleolar branch** (a. malleolaris anterior medialis) arises from the lower part of the anterior tibial artery, and is smaller than its companion on the outer side. It runs inwards, beneath the tibialis anticus tendon, ramifies over the internal malleolus, anastomosing with branches of the posterior tibial artery, and is distributed to the skin and to the ankle-joint.

(7) The **external malleolar branch** (a. malleolaris anterior lateralis), more constant and larger than the internal, passes outwards beneath the extensor longus digitorum and peroneus tertius towards the external malleolus. It anastomoses with the anterior peroneal and tarsal arteries, and supplies the ankle-joint and the adjacent articulations.

Dorsalis Pedis Artery (a. dorsalis pedis).—The dorsal artery of the foot is the direct continuation of the anterior tibial; it commences opposite the front of the ankle-joint, and extends to the posterior extremity of the first interosseous space, where it passes to the plantar aspect of the foot, and, anastomosing with the termination of the external plantar artery, completes the plantar arch.

It is covered superficially by skin and fascia, including the inferior part of the anterior annular ligament, and it is crossed, just before it reaches the first interosseous space, by the innermost tendon of the extensor brevis digitorum. It rests upon the anterior ligament of the ankle, the head of the astragalus, the astragalo-navicular ligament, the dorsum of the navicular bone, the dorsal naviculo-cuneiform and the inter-cuneiform ligaments between the internal and middle cuneiform bones. On its outer side is the internal terminal branch of the anterior

tibial nerve, which intervenes between it and the extensor brevis digitorum and innermost tendon of the extensor longus digitorum. On its inner side it is in relation with the tendon of the extensor proprius hallucis. Two venæ comites, one on each side, accompany the artery.

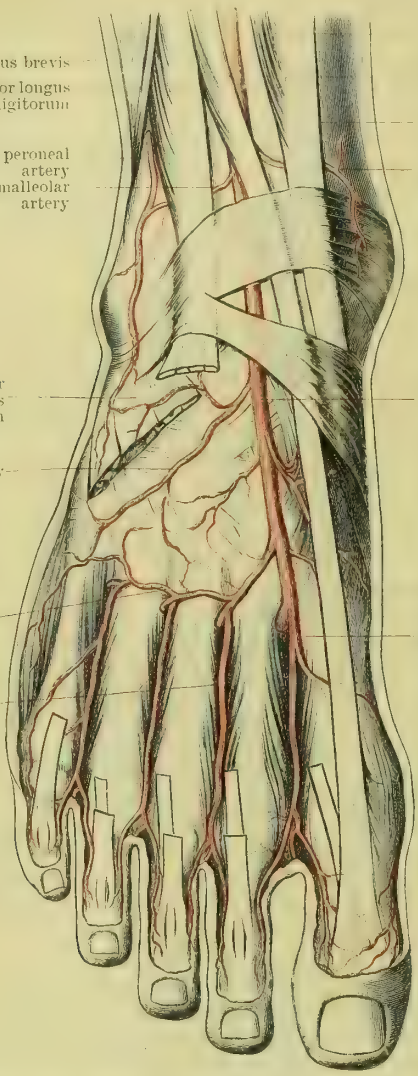


FIG. 579.—THE DORSALIS PEDIS ARTERY AND ITS BRANCHES.

As it passes through the base of the first interosseous space it lies between the two heads of the first dorsal interosseous muscle, and in the sole of the foot it is dorsal to the flexor brevis hallucis.

Branches. — On the dorsum of the foot the dorsalis pedis artery gives off cutaneous branches, the tarsal branch, the metatarsal branch, and the dorsalis hallucis or first dorsal interosseous. In the sole of the foot, and before it unites with the external plantar artery, it gives off the princeps hallucis.

(1) **Cutaneous branches**, two or three in number, are distributed to the skin on the dorsum and inner side of the foot; they anastomose with branches of the internal plantar artery.

(2) The **tarsal branch** (a. tarsea lateralis) is given off opposite the head of the astragalus; it runs outwards beneath the extensor brevis digitorum, supplying that muscle and the tarsal joints, and anastomoses with branches of the anterior peroneal, metatarsal, and external plantar arteries, and with the external malleolar artery.

(3) The **metatarsal artery** (a. arcuata) arises opposite the internal cuneiform bone. It runs outwards on the bases of the metatarsal bones, beneath the long and short extensor tendons, supplies the extensor brevis, and anastomoses with branches of the tarsal and external plantar arteries. It gives off three **dorsal interosseous arteries** (aa. metatarseæ dorsales) which run downwards on the muscles which occupy the three outer interosseous spaces to the clefts of the toes, where each divides into two *collateral digital branches* (aa. digitales dorsales) for the adjacent sides of the toes bounding the cleft to which it goes. The outer side of the little toe receives a branch from the outermost dorsal interosseous artery. Each dorsal interosseous artery gives off a *posterior perforating branch* which passes through the posterior part of the interosseous space, between the heads of the dorsal interosseous muscle, to anastomose with the plantar arch, and an *anterior perforating branch*, which descends through the anterior part of the space to anastomose with the corresponding plantar digital artery.

(4) The **dorsalis hallucis artery** (first dorsal interosseous) is continued forwards from the dorsal artery of the foot, and runs on the dorsal surface of the first dorsal interosseous muscle. It ends by dividing into collateral dorsal digital branches for the adjacent sides of the first and second toes. Before it divides it usually gives off a

dorsal digital branch which passes beneath the tendon of the extensor hallucis to the inner side of the great toe.

(5) The **princeps hallucis** (plantar digital artery) springs from the termination of the dorsalis pedis in the sole of the foot; it runs forwards in the plantar part of the first interosseous space, and divides at the interdigital cleft into collateral digital branches for the supply of the adjacent sides of the first and second toes on their plantar aspects. Before its division it supplies a plantar digital branch to the inner side of the great toe.

THE VEINS.

Veins commence at the terminations of the capillaries. They converge towards the heart, and unite with one another to form larger and still larger vessels, until finally seven large trunks are formed which open into the auricles of the heart. Three of these, the **superior vena cava**, the **inferior vena cava**, and the **coronary sinus**, belong to the *systemic circulation*; they contain venous blood, and open into the right auricle. The remaining four belong to the *pulmonary circulation*; they return arterialised blood from the lungs, and open into the left auricle.

In addition to the systemic and pulmonary veins, there is also a third group of veins, constituting the **portal system**, in which blood from the abdominal part of the alimentary canal, and from the spleen and pancreas, is conveyed to the liver. The portal system is further peculiar in that it both begins and ends in capillaries. From its terminal capillaries in the liver the hepatic veins arise, and as these open into the inferior vena cava the blood of the portal system is finally poured into the general systemic circulation. The hepatic veins also receive blood supplied to the liver by the hepatic arteries.

PULMONARY VEINS.

The terminal **pulmonary veins** (v. pulmonales, Figs. 552 and 545), two on each side, open into the left auricle of the heart. Their tributaries arise in capillary plexuses in the walls of the pulmonary alveoli. By the union of the smaller veins larger vessels are formed which run along the anterior aspects of the bronchial tubes, and, uniting together, ultimately form a single efferent vessel in each lobe, which passes into the root of the lung. Thus there are five main pulmonary veins, but, immediately after entering the root of the lung, the vessels from the upper and middle lobes of the right lung join together, and so only four terminal pulmonary veins open into the left auricle of the heart. Neither the main stems nor their tributaries possess valves.

Relations.—In the root of the lung the upper pulmonary vein on each side lies below and in front of the pulmonary artery. The lower pulmonary vein on each side is in the lowest part of the root, and it is placed much farther back than the upper vein.

On the right side the upper pulmonary vein passes behind the superior vena cava, and the lower behind the right auricle. They both terminate in the upper and back part of the left auricle close to the interauricular septum.

On the left side both upper and lower pulmonary veins cross the front of the descending aorta, and they terminate in the upper and back part of the left auricle near its left border.

All four pulmonary veins perforate the fibrous layer of the pericardium, and receive partial coverings of the serous layer before they enter the auricle.

SYSTEMIC VEINS.

The systemic veins return blood to the right auricle of the heart through the superior vena cava, the inferior vena cava, and the coronary sinus. The two first-named receive blood from the veins of the body and limbs and from most of the

solid viscera. The coronary sinus receives blood from the veins of the walls of the heart alone.

General arrangement.—The veins of the body wall and limbs form two groups—(1) the superficial veins; (2) the deep veins.

The **superficial veins**, which commence in the capillaries of the skin and subcutaneous tissues, lie in the superficial fascia, and are very numerous. They frequently anastomose with one another, and they also communicate with the deep veins, in which, after piercing the deep fascia, they terminate. They may or may not accompany superficial arteries.

The **deep veins** accompany arteries, and are known as *venæ comites.* The large arteries have only one accompanying vein, but with the medium-sized and small arteries there are usually two venæ comites, which freely anastomose with each other by short transverse branches of communication.

Visceral veins usually accompany the arteries which supply viscera in the head, neck, thorax, and abdomen. As a rule there is only one vein with each visceral artery, and, with the exception of those which enter into the formation of the portal system, they terminate in the deep systemic veins.

THE CORONARY SINUS AND THE VEINS OF THE HEART.

The **coronary sinus** (sinus coronarius, Fig. 545) is a short, but relatively wide, venous trunk which receives the majority of the veins of the heart. It lies in the inferior portion of the auriculo-ventricular sulcus, between the left auricle and the left ventricle, and it is covered superficially by some of the muscular fibres of the auricle.

It terminates in the lower and back part of the right auricle, between the orifice of the inferior vena cava above and on the right, and the right auriculo-ventricular orifice below and on the left; an imperfect valve, consisting of one or two cusps, called the **valve of Thebesius**, is situated at the opening of the sinus into the auricle.

The apertures of all the tributaries of the coronary sinus, except that of the oblique vein, are provided with valves, which, however, are frequently incompetent.

Tributaries.—(1) The **great cardiac** or **left coronary vein** (v. cordis magna, Fig. 546) commences at the apex of the heart. It ascends in the anterior interventricular sulcus to the auriculo-ventricular groove; it then turns to the left, and, passing round the left margin of the heart into the postero-inferior part of the auriculo-ventricular groove, terminates in the left extremity of the coronary sinus. It receives tributaries from the walls of both ventricles and from the wall of the left auricle. It also receives the *left marginal vein*, which commences at the lower extremity of the left margin of the heart, along which it ascends to its termination.

(2) **Small cardiac** or **right coronary vein** (v. cordis parva).—This vein is very variable; as a rule it commences at the right margin of the heart in the auriculo-ventricular sulcus, passes to the left, and terminates in the coronary sinus near its right end. It receives tributaries from the walls of the right auricle and the right ventricle; one from the latter, the *right marginal vein*, ascends along the right margin of the heart, and sometimes opens directly into the right auricle.

(3) The **oblique vein of Marshall** (v. obliqua atrii sinistri, Fig. 545) is a small venous channel which descends obliquely on the posterior wall of the left auricle and terminates in the coronary sinus. Its orifice is not provided with a valve. It is of special interest, inasmuch as it represents the left superior vena cava of some other mammals, and is developed from the left duct of Cuvier.

(4) The **inferior interventricular, inferior cardiac,** or **middle cardiac vein** (v. cordis media), commences at the apex of the heart, and, passing backwards in the inferior interventricular sulcus, terminates in the right end of the coronary sinus. It receives tributaries from the inferior parts of the walls of both ventricles.

Veins of the heart which do not end in the coronary sinus.—(*a*) The *anterior cardiac veins* (vv. cordis anteriores) are two or three small vessels which ascend on the anterior wall of the right ventricle to the auriculo-ventricular groove, where they either end separately in the right auricle or terminate in the commencement of the small cardiac vein. (*b*) The *venæ minimæ cordis.*—A number of small veins which

commence in the substance of the walls of the heart, and terminate directly in its cavities, principally in the auricles; some few, however, open into the ventricles.

THE SUPERIOR VENA CAVA AND ITS TRIBUTARIES.

The **superior vena cava** (Figs. 551 and 552) returns the blood from the head and neck, the upper extremities, the thoracic wall, and a portion of the upper part of the posterior wall of the abdomen. It is formed, immediately behind the lower part of the first right costal cartilage, by the union of the two innominate veins, and it descends, with a slight convexity to the right, to the level of the third right costal cartilage, where it opens into the upper and back part of the right auricle. It is about three inches (7·5 cm.) long; in the lower half of its extent it is enclosed within the fibrous layer of the pericardium, and it is covered in front and laterally by the serous layer.

Relations.—It is overlapped *in front* by the margins of the right lung and pleural sac and by the ascending aorta. The lung and pleura intervene between it and the second and third costal cartilages, the internal intercostal muscles in the first and second intercostal spaces, and the internal mammary vessels. It is in relation *behind* with the right vagus nerve, the vena azygos major, the right bronchus, the right pulmonary artery, and the upper right pulmonary vein. On its *left side* are the commencement of the innominate artery and the ascending portion of the aorta, whilst on the *right side* it is in close relation with the right pleura, the phrenic nerve and comes nervi phrenici vessels intervening.

Tributaries.—In addition to the two innominate veins, by the union of which it is formed, the superior vena cava only receives one large tributary, viz. the vena azygos major; but several small pericardial and mediastinal veins open into it.

The Azygos Veins.

The **vena azygos major** (v. azygos, Fig. 592) commences either from the back of the inferior vena cava, at the level of the right renal vein, or as the direct upward continuation of an anastomosing channel which connects together the lumbar veins of the right side, and which is known as the *right ascending lumbar vein*. The great azygos vein ascends through the aortic orifice of the diaphragm, and is continued upwards through the posterior mediastinum. In the upper part of its course, it first passes behind and then arches forwards above the root of the right lung to its termination in the posterior part of the superior vena cava, immediately before the latter vessel pierces the pericardium. It frequently possesses imperfect valves.

Relations.—*In the abdomen* it lies on the bodies of the upper lumbar vertebræ, behind the right crus of the diaphragm and the inferior vena cava, and to the right side of the thoracic duct.

In the thorax it lies on the bodies of the lower eight dorsal vertebræ, the intervening discs, and the anterior common ligament, and it crosses in front of the right aortic intercostal arteries. In the lower part of the posterior mediastinum it is covered in front by the right pleura and lung; at a higher level it is overlapped by the right margin of the œsophagus, and immediately before its termination it is crossed by the root of the right lung.

On its right side it receives the right posterior intercostal veins. On its left side it is in relation, in the greater part of its extent, with the thoracic duct and, as it arches forwards over the root of the lung, with the right vagus nerve. About the level of the seventh dorsal vertebra it receives the vena azygos minor superior, whilst at the level of the eighth dorsal vertebra the vena azygos minor inferior opens into it.

In addition to the left azygos veins it receives the right posterior intercostal veins, except that from the first space but including the right superior intercostal vein, the right subcostal vein, and, through the ascending lumbar vein, the upper right lumbar veins. It also receives the right bronchial veins and some small œsophageal, pericardial, and mediastinal tributaries.

The **vena azygos minor superior** (v. hemiazygos accessoria) is formed by the union of the fourth, fifth, sixth, and seventh left posterior intercostal veins. It lies in the posterior mediastinum on the left sides of the bodies of the fifth, sixth, and seventh dorsal vertebræ, and crosses the spine from left to right opposite the body of the seventh dorsal vertebra, passing behind the aorta, œsophagus, and thoracic duct; it terminates in the vena azygos

major. It receives the left bronchial veins, some small posterior mediastinal veins also open into it, and it communicates with the left superior intercostal vein.

The **vena azygos minor inferior** (v. hemi-azygos) commences in the epigastric region. At its origin it is connected either with the left ascending lumbar vein or with the left renal vein. After piercing the left crus of the diaphragm it ascends on the left sides of the bodies of the lower dorsal vertebræ, and opposite the eighth dorsal vertebra it turns to the right, crosses the front of the spine behind the aorta, œsophagus, and thoracic duct, and terminates in the vena azygos major. As it ascends in the posterior mediastinum it lies internal to the sympathetic cord, behind the roots of the splanchnic nerves, and superficial to the lower left intercostal arteries. Through the left ascending lumbar vein it receives blood from the upper lumbar veins of the left side; the lower four posterior intercostal veins, the left subcostal vein, and small mediastinal tributaries also terminate in it.

Not infrequently the upper and lower minor azygos veins unite, opposite the seventh or eighth dorsal vertebra, to form a common trunk which terminates in the azygos major.

The **bronchial veins** do not quite correspond to the bronchial arteries, and they are not found on the walls of the smallest bronchi. On each side the tributaries run in front of and behind the bronchial tubes to the root of the lung, where they unite, as a rule, into two small trunks; those of the right side open into the vena azygos major, and those of the left into the vena azygos minor superior, or into the left superior intercostal vein. On both sides they are joined by tracheal and posterior mediastinal veins. Some few small bronchial veins, including most of those from the smaller tubes, open into the pulmonary veins.

Intercostal Veins.—There are two sets of intercostal veins (vv. intercostales), the anterior and the posterior.

The **anterior intercostal veins** are tributaries of the internal mammary or of the musculo-phrenic veins, and are described with those vessels (p. 829).

The **posterior intercostal veins** (Fig. 592) are eleven in number on each side. A single vein runs in each intercostal space; it is situated in the subcostal groove above the corresponding artery.

On the right side the posterior intercostal vein of the first space accompanies the superior intercostal artery across the front of the neck of the first rib, and terminates in the vertebral or innominate vein. The second, third, and fourth intercostal veins of the right side unite together to form a common trunk, the **right superior intercostal vein** (v. intercostalis suprema dextra), which terminates by joining the vena azygos major. The fifth to the eleventh posterior intercostal veins of the right side open separately in the vena azygos major.

On the left side the first posterior intercostal vein follows a course similar to that taken by the corresponding vein on the right side, and terminates in the left vertebral or innominate vein. The second, third, and fourth posterior intercostal veins of the left side unite to form the **left superior intercostal vein** (v. intercostalis suprema sinistra), which runs from behind forwards along the left and anterior aspect of the aortic arch. It passes obliquely between the left vagus and phrenic nerves, crosses the root of the left subclavian artery, and ends in the lower part of the left innominate vein. The fifth, sixth, seventh, and eighth posterior intercostal veins of the left side terminate in the vena azygos minor superior, and the ninth, tenth, and eleventh in the vena azygos minor inferior.

Each posterior intercostal vein is provided with valves, both at its termination and along its course, which prevent the blood flowing towards the anterior aspect of the thoracic wall. Its tributaries are derived from the adjacent muscles and bones, and a short distance from its termination it receives a dorsal tributary which passes forwards to it between the transverse processes of the vertebræ. This dorsal vessel is formed by the union of small veins which issue from the muscles of the back, from the anterior and posterior spinal plexuses which lie respectively in front of the bodies and behind the arches of the vertebræ, and by venous channels which issue through the intervertebral foramina; the latter vessels commence in the spinal canal, where they are connected with the anterior and posterior spinal veins.

The Innominate Veins.

The **innominate** or **brachio-cephalic veins** (vv. anonymæ dextra et sinistra, Figs. 551 and 552), two in number, right and left, return blood from the head and neck, the upper extremities, the upper part of the posterior wall of the thorax, the

anterior wall of the thorax, and the upper part of the anterior wall of the abdomen. Each innominate vein commences behind the sternal end of the clavicle of the corresponding side, and is formed by the union of the internal jugular and subclavian veins; the two innominate veins terminate by uniting together, behind the lower border of the cartilage of the first rib on the right side, to form the superior vena cava. To reach this point the left vein has to pass from left to right behind the manubrium sterni, and it is therefore about three times as long as the right vein. The innominate veins do not possess valves.

The **right innominate vein** is a little more than one inch (3 cm.) in length. It descends almost vertically to the lower border of the first costal cartilage, and terminates in the superior vena cava.

Relations.—It is overlapped in front by the right lung and pleural sac, and is in relation with the sternal end of the clavicle and the sterno-hyoid and sterno-thyroid muscles. It partly overlaps the innominate artery, which lies to its left side, and it is in front of the right vagus nerve and the posterior part of the upper end of the right pleural sac. The phrenic nerve and the accompanying vessels run along its right side, and intervene between it and the right pleural sac.

Tributaries.—In addition to the veins by the union of which it is formed, the right innominate vein receives the right vertebral and internal mammary veins, and sometimes the right inferior thyroid vein and the first right posterior intercostal vein. The right lymphatic duct also opens into it.

The **left innominate vein** passes from left to right, with a slight obliquity downwards, behind the upper part of the manubrium sterni, to the lower border of the first right costal cartilage, where it terminates in the superior vena cava It is a little less than three inches long (6 to 7·5 cm.).

Relations.—It is covered in front, in the greater part of its extent, by the left pleura, but at its right extremity it is slightly overlapped by the right pleura, and in the middle line the remains of the thymus gland intervene between it and the posterior surface of the sternum. It rests posteriorly upon the left subclavian artery, the left phrenic, and the left vagus nerves, the left superior cardiac branch of the sympathetic, the inferior cervical branch of the left vagus, the left common carotid artery, the trachea, and the innominate artery.

Its lower border is in relation with the arch of the aorta, and on its upper border it receives the inferior thyroid vein of one or both sides.

Tributaries.—It receives the vertebral, internal mammary, inferior thyroid, and superior intercostal veins of its own side, the first left posterior intercostal vein, and some pericardial, thymic, anterior bronchial, and anterior mediastinal veins. Sometimes the right inferior thyroid vein joins it, but usually this vessel terminates in the right innominate vein or in the commencement of the superior vena cava.

The thoracic duct opens into it just at the angle of junction of the internal jugular and subclavian veins.

Internal mammary veins (vv. mammariæ internæ).—Each internal mammary artery is accompanied by venæ comites; they commence by the union of the venæ comites of the superior epigastric and musculo-phrenic arteries, between the sixth costal cartilage and the triangularis sterni, and at the upper part of the thorax they fuse into a single vessel which enters the superior mediastinum and ends in the innominate vein of the same side.

The tributaries of the internal mammary veins are—(*a*) The **venæ comites** of the **superior epigastric** and **musculo-phrenic arteries**, which in their turn receive tributaries which correspond with the branches of the arteries they accompany. (*b*) Six **anterior perforating veins** which accompany the corresponding arteries, one lying in each of the upper six intercostal spaces. (*c*) Twelve **anterior intercostal veins** from the upper six intercostal spaces, two veins lying in each space with the corresponding branches of the internal mammary artery. (*d*) Small and irregular **pleural, muscular, mediastinal,** and **sternal veins.**

The internal mammary veins are provided with numerous valves which prevent the blood from flowing downwards.

Superior epigastric veins (vv. epigastricæ superiores).—The venæ comites of the superior epigastric artery receive tributaries from the substance of the rectus abdominis, the sheath of the muscle, and the superjacent skin and fascia; they pass with the artery,

between the sternal and costal origins of the diaphragm, and terminate in the internal mammary veins.

Musculo-phrenic veins.—The venæ comites of the musculo-phrenic artery commence in the abdomen, pass through the diaphragm with the artery, and terminate in the internal mammary veins. They receive as tributaries the anterior intercostal veins of the seventh, eighth, and ninth intercostal spaces, and small venules from the substance of the diaphragm.

Vertebral Veins (vv. vertebrales).—These correspond only to the extra-cranial parts of the vertebral arteries. Each commences by the union of offsets from the intraspinal venous plexuses, and, issuing from the spinal canal, passes across the posterior arch of the atlas with the vertebral artery to the foramen in the transverse process of the atlas. It then descends through the foramina in the cervical transverse processes, and breaks up into a plexus of venous channels which surround the artery. At the lower part of the neck these channels unite to form a single trunk which issues from the foramen in the transverse process of the sixth cervical vertebra, and descends, in the interval between the longus colli and scalenus anticus muscles, to terminate in the upper and back part of the innominate vein, where it possesses a uni- or bi-cuspidate valve.

Relations.—In the first part of its course the vein lies in the suboccipital triangle. The second, plexiform portion, is in the canal formed by the foramina in the transverse processes of the cervical vertebræ, and, with the artery which it surrounds, lies in front of the trunks of the cervical spinal nerves. The third part, in the root of the neck, is between the longus colli and scalenus anticus muscles, in front of the first part of the vertebral artery, and behind the internal jugular vein.

Tributaries.—In addition to the offsets from the intraspinal venous plexuses by the union of which it is formed, each vertebral vein receives the following tributaries:—(*a*) Small vessels which issue from the muscles, ligaments, and bones of the deeper parts of the neck, and the lower and back part of the head. (*b*) Offsets from the intraspinal venous plexuses which pass out of the spinal canal by the intervertebral foramina. (*c*) The **anterior deep cervical** or **anterior vertebral vein**, a vessel which is formed by the union of tributaries which issue from a venous plexus which lies in front of the bodies and on the roots of the transverse processes of the cervical vertebræ. This vessel accompanies the ascending cervical artery, and terminates in the lower part of the vertebral vein, immediately after the latter has issued from the foramen in the sixth cervical transverse process. (*d*) The **posterior deep cervical** (v. cervicalis profunda) or **posterior vertebral vein**; this commences in the suboccipital triangle from a venous plexus with which the vertebral and occipital veins communicate. It descends behind the transverse processes of the cervical vertebræ in company with the profunda cervicis artery, turns forwards at the root of the neck, between the transverse processes of the sixth and seventh cervical vertebræ or between the latter and the neck of the first rib, and opens into the vertebral vein. It receives blood from the muscles, ligaments, and bones of the back of the neck. (*e*) The **posterior intercostal vein** from the first intercostal space sometimes opens into it.

Occasionally the venous plexus round the vertebral artery ends below in two terminal trunks, anterior and posterior, instead of one. In these cases the second terminal vessel lies behind the lower part of the vertebral artery, passes through the foramen in the transverse process of the seventh cervical vertebra, and turns forwards on the outer side of the artery to join the anterior trunk, thus forming a common terminal vein which ends in the usual manner.

Inferior Thyroid Veins (vv. thyreoideæ inferiores).—Each inferior thyroid vein commences by the union of a series of tributaries which issue from the isthmus and the corresponding lateral lobe of the thyroid body. The two veins descend along the front of the trachea into the superior mediastinum, where the right inferior thyroid vein terminates in the junction of the two innominate veins, and the left in the upper part of the left innominate vein; or the two veins unite to form a single trunk, which usually ends in the left innominate vein, but occasionally in the right. In their descent through the neck the inferior thyroid veins frequently anastomose together, and sometimes these anastomoses are so frequent and irregular that a venous plexus is formed in front of the lower cervical portion of the trachea.

VEINS OF THE HEAD AND NECK.

Internal jugular veins (Figs. 552 and 582).—Each internal jugular vein (v. jugularis interna) commences in the posterior compartment of the jugular foramen, as the direct continuation of the lateral sinus, and terminates behind the cartilage of the first rib by uniting with the subclavian vein of the same side to form the innominate vein.

At its commencement it is dilated, forming the bulb of the jugular vein, and in this situation it lies behind and somewhat to the outer side of the internal carotid artery and the last four cranial nerves. As it descends it accompanies first the internal and then the common carotid artery; inclining forwards during its descent, it gradually passes from its original position, behind and to the outer side of the internal carotid artery, and lies more completely to the outer side of the internal and common carotid arteries, and indeed somewhat overlaps the latter in front. This is more especially the case on the left side, for both internal jugular veins trend slightly towards the right as they descend; consequently at the root of the neck the right vein is separated from the right common carotid artery by a small interval filled by areolar tissue, whilst the left vein is more directly in front of the corresponding common carotid artery.

Within an inch of its lower extremity each internal jugular vein is provided with a valve consisting of one or two cusps, which, however, is frequently incompetent.

Relations.—The vein lies in front of the transverse processes of the cervical vertebræ, the rectus capitis lateralis, rectus capitis anticus major, and scalenus anticus muscles, the ascending cervical artery, which runs upwards in the interval between the attachments of the two latter muscles, and the phrenic nerve; the suprascapular and the transverse cervical arteries intervene between it and the scalenus anticus. At the root of the neck the vein lies in front of the first part of the subclavian artery and the origins of the vertebral artery and the thyroid axis, and on the left side it is in front of the terminal part of the thoracic duct.

On the inner side of the internal jugular vein, immediately below the skull, are the internal carotid artery and the last four cranial nerves; in the rest of its extent it is in relation internally either with the internal or the common carotid artery, whilst to its inner side and somewhat posteriorly, between it and the large arteries, lies the vagus nerve.

Each internal jugular vein is covered in the whole of its length by the sterno-mastoid muscle; near its upper end it is crossed by the posterior belly of the digastric, whilst in its lower half, in addition to the sterno-mastoid, the omo-hyoid, the sterno-hyoid, and the sterno-thyroid muscles are superficial to it. Just below the transverse process of the atlas, and under cover of the sterno-mastoid, the vein is crossed on its outer side by the spinal accessory nerve and by the occipital artery; about the middle of its course it is also crossed by the communicans cervicis nerve, and near its lower end by the anterior jugular vein; the latter vessel, however, is separated from it by the sterno-hyoid and sterno-thyroid muscles. Superficial to the vein are numerous deep cervical lymphatic glands.

Tributaries.—(*a*) The **inferior petrosal sinus**, which joins it near its commencement. (*b*) **Pharyngeal branches** from the venous plexus on the wall of the pharynx. (*c*) The **common facial vein**, which receives the facial vein and its tributaries. (*d*) The **lingual veins** (vv. linguales), small venæ comites, which commence chiefly in the sublingual and dorsalis linguæ veins, and accompany the first and second parts of the lingual artery. (*e*) The **ranine vein**, which commences beneath the tip of the tongue, and accompanies at first the two terminal parts of the lingual artery, and afterwards the hypoglossal nerve. (*f*) The **superior thyroid vein** (v. thyreoidea superioris), which accompanies the corresponding artery. (*g*) The **middle thyroid vein**, which passes backwards from the lateral lobe of the thyroid body and crosses the middle of the outer aspect of the common carotid artery. (*h*) The **occipital vein** (v. occipitalis) occasionally terminates in the internal jugular vein. In many cases, however, it ends in the suboccipital plexus, which is drained by the vertebral and deep cervical veins (see p. 830).

The **common facial vein** (v. facialis communis) is formed by the union of the **facial vein** (v. facialis anterior) with the anterior division, or terminal branch, of a venous trunk which lies in substance of the parotid gland, and which is called the **temporo-maxillary vein** (v. facialis posterior). It accompanies the first part of the facial artery

in the carotid triangle, passes beneath the sterno-mastoid, and terminates in the anterior border of the internal jugular vein. Just before it disappears beneath the sterno-mastoid, the common facial vein frequently gives off a large branch, which descends along the anterior border of the sterno-mastoid to the suprasternal fossa, where it joins the anterior jugular vein.

The **facial vein** (v. facialis anterior, Fig. 580) commences at the inner angle of the orbit in the angular vein, which is formed by the union of the supraorbital and frontal veins. It passes downwards and backwards on the face, from the inner angle of the orbit to the lower and anterior part of the masseter muscle, which it crosses, lying in the same plane as the facial artery, but following a much straighter course. After crossing the lower border of the jaw it passes across the submaxillary triangle, superficial to the submaxillary gland, by which it is separated from the facial artery, which here lies in a deeper plane, and it terminates a short distance below the angle of the jaw by uniting with the anterior division of the temporo-maxillary vein to form the common facial vein.

The facial vein receives tributaries corresponding with all the branches of the facial artery, except the ascending palatine and the tonsillar, which have no accompanying veins, the blood from the region which they supply being returned for the most part through the pharyngeal plexus. The facial vein also communicates, by means of an anastomosing channel, called the **deep facial vein**, which passes backwards between the masseter and buccinator muscles into the zygomatic fossa, with the pterygoid plexus which surrounds the external pterygoid muscle.

The **inferior thyroid veins** have already been described (see p. 830).

Subclavian Veins.—The subclavian vein (v. subclavia) of each side is the direct continuation of the main vein of the upper extremity, the axillary vein; but through its tributary, the external jugular vein, it also receives blood both from the superficial and deep parts of the head and neck.

From its commencement at the outer border of the first rib it runs inwards below and in front of the corresponding artery, from which it is separated by the lower part of the scalenus anticus muscle, and it terminates behind the sternal end of the clavicle, in the innominate vein of the corresponding side. As it passes inwards it forms a slight curve, the convexity of which is directed upwards.

Each subclavian vein possesses a single bicuspid valve which is situated immediately on the distal side of the opening of the external jugular vein.

Relations.—The subclavian vein is in relation in front with the posterior layer of the costo-coracoid membrane, which separates it from the subclavius muscle, and the nerve to the subclavius, and with the back of the sternal end of the clavicle, from which it is separated, however, by the fibres of the sterno-hyoid and sterno-thyroid muscles.

It is closely attached in front to the posterior surface of the costo-coracoid membrane, consequently it is expanded when the clavicle is moved forwards, a condition of affairs which constitutes a distinct danger when operations are being performed in the neighbourhood of the vein, for in the event of the vessel being wounded, forward movement of the clavicle may cause air to be sucked into the vein with fatal results.

Behind the vein are the first and third parts of the subclavian artery, but it is separated from the second part by the scalenus anticus. To the inner side of the anterior scalene the posterior relations of the vein, in addition to the subclavian artery, are the upper part of the internal mammary artery, the phrenic nerve, and the cervical portion of the pleura.

It rests below upon the upper surface of the first rib.

Tributaries.—Whilst the subclavian vein is the direct continuation of the axillary vein, and receives the blood from the upper extremity, it has, as a general rule, only one named tributary, viz. the external jugular vein.

The **external jugular vein** (v. jugularis externa, Fig. 580) is formed on the superficial surface of the sterno-mastoid muscle, a little below and behind the angle of the jaw, by the union of the posterior auricular vein with the posterior terminal branch of the *temporo-maxillary vein.* After its formation the external jugular vein descends, with a slight obliquity backwards, to the anterior part of the subclavian portion of the posterior triangle of the neck, where it pierces the deep fascia, and, after crossing in front of the third part of the subclavian artery, terminates in the subclavian vein.

Whilst on the surface of the sterno-mastoid muscle it is covered by the superficial fascia and platysma muscle, and it lies parallel with, and slightly in front of, the great auricular nerve; after crossing the transverse cervical nerve it reaches the posterior border of the sterno-mastoid, where it receives a tributary called the **posterior external jugular vein**, which commences in the superficial tissues of the upper and back part of the neck, and runs downwards and forwards across the roof of the upper part of the posterior cervical triangle to its termination in the external jugular vein.

As the external jugular vein pierces the deep cervical fascia in the subclavian

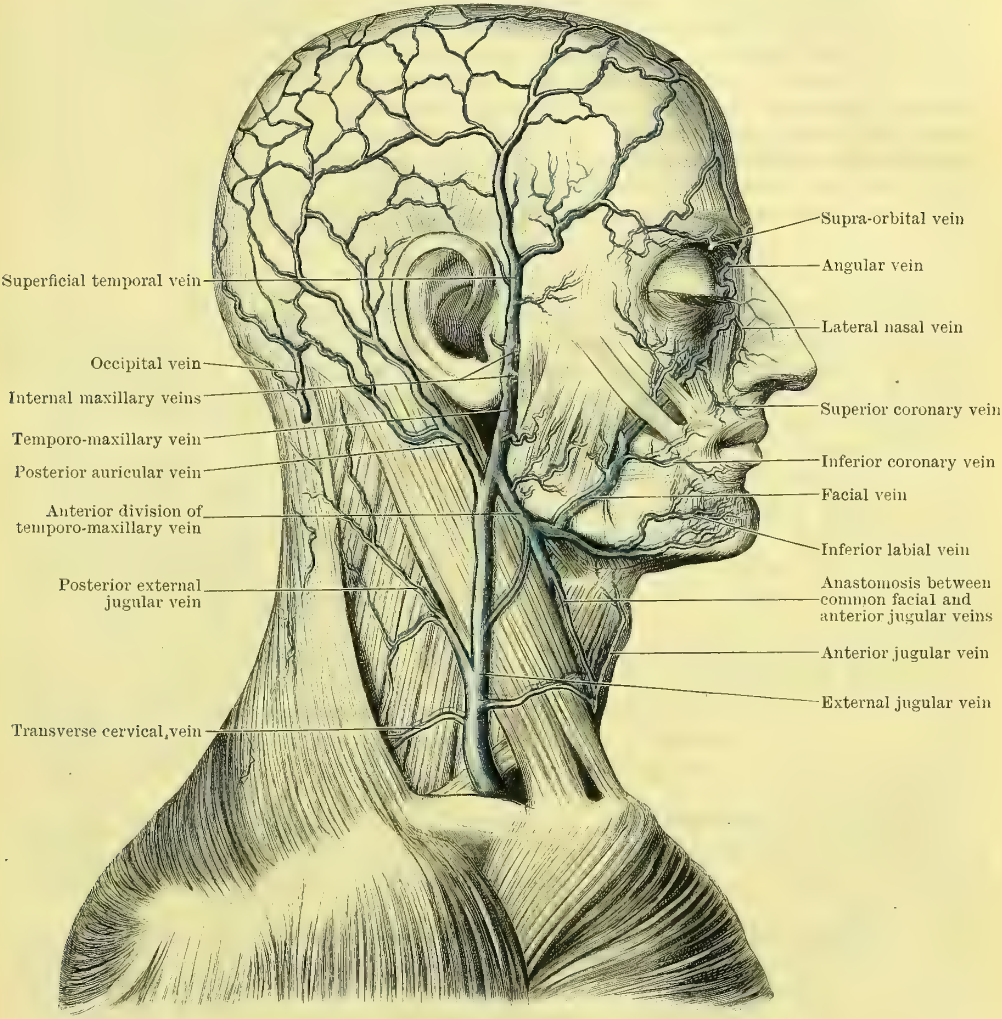


FIG. 580.—SUPERFICIAL VEINS OF THE HEAD AND NECK.

triangle, its wall is closely attached to the margin of the opening through which it passes, and as it is crossing in front of the third part of the subclavian artery it is joined by the suprascapular, transverse cervical, and anterior jugular veins.

There are usually two valves in the lower part of the vein—one, which is generally incompetent, at its termination, and a second at a higher level; this is frequently competent.

Tributaries.—In addition to the posterior auricular vein and the posterior division of the temporo-maxillary vein by which it is formed, the external jugular vein receives the posterior external jugular vein, which has already been described, the transverse cervical and suprascapular veins from the region of the shoulder, and the anterior jugular vein. Occasionally the cephalic vein also opens into it.

The **posterior auricular vein** (v. auricularis posterior, Fig. 580) receives tributaries from the posterior parts of the parietal and temporal regions and from the inner surface of the pinna. It is considerably larger than the posterior auricular artery, which it only accompanies in the scalp. At the base of the scalp it leaves the artery and descends in the superficial fascia, over the upper part of the sterno-mastoid, to open into the commencement of the external jugular vein.

The posterior division of the **temporo-maxillary vein** (see p. 835).

The **transverse cervical** and **suprascapular veins** accompany the corresponding arteries; not infrequently they open directly into the subclavian vein.

The **anterior jugular vein** (v. jugularis anterior) commences over the anterior belly of the digastric muscle, and is formed by the union of small veins from the lower lip and the submental region. It descends in the superficial fascia, at a variable distance from the middle line, and perforates the superficial layer of the deep fascia just above the inner end of the clavicle. It there enters the space above the manubrium sterni, which lies between the first and second layers of the deep cervical fascia, and which is called Burns's space, where, after anastomosing with its fellow of the opposite side and receiving a communication from the facial vein, it turns outwards, between the sterno-mastoid superficially and the sterno-hyoid, sterno-thyroid, and scalenus anticus muscles deeply, to terminate at the outer border of the latter muscle in the external jugular vein.

The Veins of the Scalp.

The veins which drain the blood from the superficial parts of the scalp are the frontal, the supra-orbital, the superficial temporal, the posterior auricular, and the occipital. The blood from the deeper part of the scalp, in the region of the temporal fossa on each side, passes into the deep temporal veins, which are tributaries of the pterygoid plexus.

The **frontal** (v. frontalis) and **supra-orbital veins** (v. supra-orbitalis) receive blood from the inner and front part of the scalp. They unite together, near the inner angle of the orbit, to form the *angular vein*; before the union is effected the supra-orbital vein sends a branch backwards through the supra-orbital notch into the orbital cavity, where it terminates in the ophthalmic vein, and as this branch passes through the notch it receives the frontal diploic vein (p. 836).

The **superficial temporal vein** (v. temporalis superficialis) receives tributaries from the outer part of the frontal region, from the greater part of the superficial area of the temporal region, and from the anterior part of the parietal region. It passes downwards, across the posterior root of the zygoma, into the parotid gland, where it unites with the internal maxillary vein to form the temporo-maxillary trunk.

The **posterior auricular vein** (v. auricularis posterior) drains the posterior portions of the temporal and parietal areas of the scalp. It runs downwards across the mastoid portion of the temporal bone, and terminates in the external jugular vein.

The **occipital vein** (v. occipitalis, Fig. 580) receives tributaries from the inner and posterior part of the parietal region and from the occipital region. As a rule it pierces the occipital origin of the trapezius, and, passing deeply into the sub-occipital triangle, terminates in a plexus of veins which is drained by the vertebral and deep cervical veins. It sometimes communicates with the external jugular vein, and occasionally an offset from it accompanies the corresponding artery and ends in the internal jugular vein.

It generally receives the mastoid emissary vein; one of its tributaries receives the parietal emissary vein, and occasionally an emissary vein from the torcular Herophili opens into it.

The Veins of the Orbit, the Nose, and the Pterygo-Maxillary Region.

The veins of these three regions are closely associated together; for although the orbital blood is returned for the most part to the cavernous sinus by the ophthalmic vein, the latter vein is closely connected with the pterygoid plexus which lies in the pterygo-maxillary region.

Veins of the Orbit.—The veins of the orbit correspond, with the exception of the frontal vein, with the branches of the ophthalmic artery, and they gradually converge, as they pass backwards in the orbit, until they form two main trunks, an upper (v. ophthalmica superior) and a lower (v. ophthalmica inferior); these terminate, separately or by a single trunk, in the anterior end of the cavernous sinus, to which they pass through the foramen lacerum anterius, and between the two heads of the external rectus muscle.

The superior ophthalmic vein communicates, at the internal angle of the orbit, with the angular vein, and the inferior ophthalmic vein communicates through the spheno-maxillary fissure with the pterygoid plexus.

Veins of the Nose.—The veins of the walls of the nasal cavity end partly in the ethmoidal tributaries of the superior ophthalmic vein, partly in the septal affluent of the superior coronary and in the lateral nasal veins, both of which are tributaries of the facial vein; but the majority of the veins of the nose, both from the septal and outer walls, join together to form a spheno-palatine vein which passes through the spheno-palatine foramen and the spheno-maxillary fossa, and terminates in the pterygoid plexus.

Pterygoid Plexus and the Internal Maxillary Vein.—The **pterygoid plexus** (plexus pterygoideus) of veins lies in the zygomatic and pterygoid fossæ. It covers the inner surface of the internal pterygoid muscle, and surrounds the external pterygoid. It receives tributaries which correspond with and accompany the branches of the internal maxillary artery—viz. spheno-palatine, pterygo-palatine, vidian, infraorbital, posterior superior dental, posterior palatine, buccal, two or three deep temporal, pterygoid, masseteric, and inferior dental veins, and the vena comites of the middle meningeal artery. It communicates superiorly with the cavernous sinus through the foramen ovale, anteriorly with the inferior ophthalmic vein through the spheno-maxillary fissure, and between the masseter and the buccinator with the facial vein by the deep facial anastomosing branch. It also communicates posteriorly and internally, on the inner side of the internal pterygoid, with the pharyngeal plexus, and it terminates posteriorly in the internal maxillary vein.

The **internal maxillary vein** is a short vessel which accompanies the first part of the internal maxillary artery, between the spheno-mandibular ligament and the neck of the lower jaw; it enters the parotid gland, and terminates by uniting with the superficial temporal vein to form the temporo-maxillary trunk. Occasionally the internal maxillary vein is double.

The **temporo-maxillary vein** (v. facialis posterior) is a short trunk which is formed in the upper part of the parotid gland, behind the neck of the jaw, by the union of the superficial temporal and internal maxillary veins. As it descends it lies superficial to the external carotid artery, and it is crossed by the cervico- and temporo-facial branches of the facial nerve. It terminates at the lower part of the parotid gland by dividing into posterior and anterior divisions. The posterior division passes backwards, perforates the deep cervical fascia, and unites on the upper part of the sterno-mastoid muscle with the posterior auricular vein to form the external jugular vein. The anterior division passes downwards and forwards into the carotid triangle, where it terminates in the common facial vein.

VENOUS SINUSES AND VEINS OF THE CRANIUM, AND OF ITS CONTENTS.

The venous channels met with in the cranial walls and cranial cavity are:—

(1) The diploic veins (vv. diploicæ), which lie in the cancellous tissue between the outer and inner tables of the cranial bones.

(2) The meningeal veins, which accompany the meningeal arteries in the outer layer of the dura mater.

(3) The veins of the brain, which lie between the folds of pia mater and in the subarachnoid space.

(4) The cranial venous sinuses, channels which are situated between the outer

and inner layers of the dura mater; they receive the blood from the terminal cerebral veins.

Diploic and Meningeal Veins.

The **diploic veins** (vv. diploicæ) are anastomosing spaces in the cancellous tissue of the flat bones of the skull; they are lined by endothelium. The number of efferent vessels which emerge from these spaces is not constant, but usually there are at least four—viz. a frontal, two temporal, anterior and posterior, and an occipital.

The **frontal diploic vein** (v. diploica frontalis) is one of the most constant; it drains the anterior part of the frontal bone, and, passing through a small aperture in the upper margin of the supraorbital notch, terminates in the supraorbital vein.

The **anterior temporal diploic vein** (v. diploica temporalis anterior) drains the

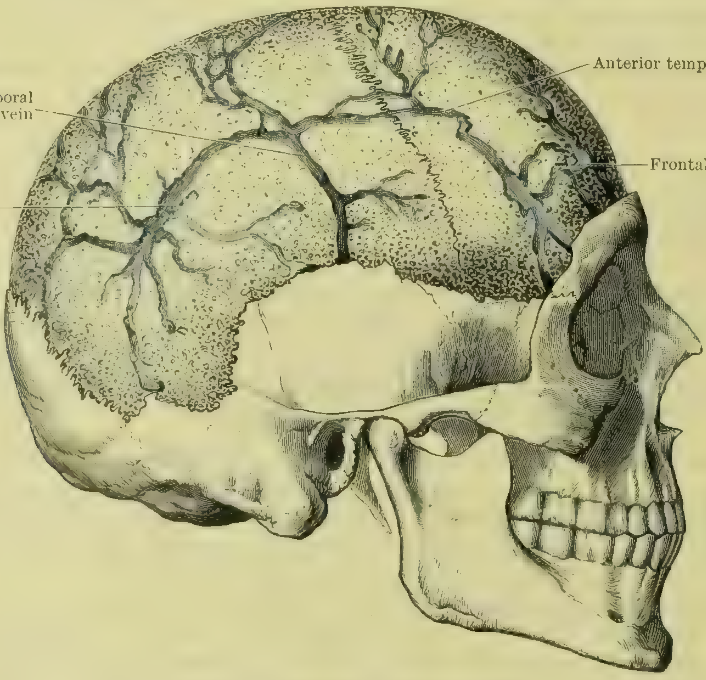


Fig. 581.—The Veins of the Diploë.

posterior part of the frontal bone, and the anterior part of the parietal bone; it pierces the great wing of the sphenoid, and terminates either in the spheno-parietal sinus or in the anterior deep temporal vein.

The **posterior temporal diploic vein** (v. diploica temporalis posterior) drains the posterior part of the parietal bone; it runs downwards to the posterior inferior angle of the parietal bone and terminates in the lateral sinus, to which it passes either through a foramen in the inner table of the parietal bone or through the mastoid foramen.

The **occipital diploic vein** (v. diploica occipitalis) is usually the largest of the series; it drains the occipital bone, and terminates either externally in the occipital vein or internally in the lateral sinus.

The **meningeal veins** (vv. meningeæ) commence in two capillary plexuses, a deep and a superficial. The deep plexus is a wide-meshed network in the inner layer of the dura mater. Its efferent vessels terminate in the superficial plexus. The superficial plexus lies in the outer layer of the dura mater. It consists of numerous vessels of uniform calibre which frequently anastomose together, and terminate in two sets of efferents; of these, one set terminates in the cranial blood sinuses, and the other accompanies the meningeal arteries. The efferent meningeal

veins are peculiar, inasmuch as they do not increase in size as they approach their terminations, and they are irregular in their relations to the arteries; as a rule the middle meningeal arteries alone possess two venæ comites, the other meningeal arteries usually having only one accompanying vein.

Veins of the Brain.

The veins of the brain include the veins of the cerebrum, of the mid-brain, of the cerebellum, of the pons, and of the medulla oblongata. They do not possess valves.

Veins of the Cerebrum (vv. cerebri).—The cerebral veins are arranged in two groups, (*a*) the deep and (*b*) the superficial.

The deep veins issue from the substance of the brain. The superficial veins lie upon its surface in the pia mater and the subarachnoid space. The terminal trunks of both sets pierce the arachnoid membrane and the inner layer of the dura mater, and open into the cranial venous sinuses.

(*a*) The **deep cerebral veins** are the choroid veins, the veins of the corpora striata, the veins of Galen, and the inferior striate veins.

Each **choroid vein** (v. chorioidea) is formed by the union of tributaries which issue from the choroid plexus in the descending horn of a lateral ventricle. It ascends along the lateral border of the velum interpositum, and passes forwards in the outer border of that fold of pia mater to the foramen of Monro, where it receives efferents from the choroid plexus of the third ventricle, and ends by uniting with the vein of the corpus striatum to form the vein of Galen.

The **vein of the corpus striatum**, on each side, is formed by the union of tributaries which issue from the corpus striatum and from the optic thalamus. It runs forwards between these bodies, in a groove in the floor of the lateral ventricle, and, after receiving tributaries from the walls of the anterior horn of the ventricle, including the septum lucidum, it terminates at the apex of the velum interpositum, where it joins the choroid vein to form the vein of Galen.

The **veins of Galen** are three in number—a right and a left vein, and the vena magna Galeni.

Each lateral vein of Galen commences at the apex of the velum interpositum, near the foramen of Monro, by the union of the vein of the corpus striatum with the choroid vein. The two veins run backwards between the layers of the velum, and terminate beneath the splenium of the corpus callosum by uniting to form the vena magna Galeni.

The tributaries which enter each vein, after its formation, are the basilar vein, the efferent veins from the choroid plexus of the third ventricle, and veins from the posterior part of the corpus callosum, the pineal body, the corpora quadrigemina, and the walls of the posterior cornu of the lateral ventricle.

The **vena magna Galeni** (v. cerebri magna [Galeni]) passes backwards and slightly upwards from its origin, and ends in the anterior extremity of the straight sinus. In addition to the two veins of Galen, by the union of which it is formed, it receives tributaries from the posterior parts of the callosal convolutions, from the inner and tentorial surfaces of the occipital lobes of the brain, and from the upper surface of the cerebellum.

An **inferior striate vein** descends on each side from the substance of the corpus striatum, and, after passing through the anterior perforated space, ends in the basilar vein (p. 838), which, as already stated, is a tributary of the corresponding lateral vein of Galen.

(*b*) The **superficial cerebral veins** are more numerous and of larger calibre than the cerebral arteries. They lie upon the surface of the cerebrum, they drain blood from the cerebral cortex, and they are divisible into two sets, the superior and the inferior.

The **superior cerebral veins** (vv. cerebri superiores), twelve or more in number, lie in the pia mater and subarachnoid space on the upper and outer aspect of the cerebral hemispheres. They run inwards to the margin of the longitudinal fissure,

where they receive tributaries from the inner surface of the hemispheres, and they terminate in the superior longitudinal sinus. The anterior veins of this set are small and run transversely inwards, but the posterior are large and run obliquely forwards and inwards; they are embedded for some distance in the wall of the sinus, and their orifices are directed forwards, against the blood-stream.

The **inferior cerebral veins** (vv. cerebri inferiores) lie on the lower and outer aspects of the cerebral hemispheres; they run downwards and inwards, and terminate in the sinuses which lie at the base of the skull—viz. the cavernous, the superior petrosal, and the lateral sinuses. One of these veins, the **superficial Sylvian vein**, runs along the posterior horizontal limb and stem of the fissure of Sylvius to the cavernous sinus; occasionally it is united by an anastomotic loop, known as the **great anastomotic vein** of Trolard, with the superior longitudinal sinus, and sometimes by the **posterior anastomotic vein** with the lateral sinus.

The **anterior cerebral vein** of each side lies in the great longitudinal fissure and accompanies the corresponding anterior cerebral artery; it receives tributaries from the corpus callosum and the callosal convolution. Turning downwards round the genu of the corpus callosum, it reaches the base of the brain, and terminates in the basilar vein.

The **deep Sylvian vein** lies deeply in the fissure of Sylvius; it anastomoses freely with the superficial Sylvian vein, receives tributaries from the Island of Reil and the adjacent opercula, and terminates in the basilar vein.

The **basilar vein** commences at the anterior perforated space; it is formed by the union of the anterior cerebral vein with the deep Sylvian vein and with the inferior striate vein. Passing backwards round the crus cerebri, it terminates in a vein of Galen. Its tributaries are derived from the tuber cinereum, the corpus albicans, the posterior perforated space, the uncinate gyrus, the inferior cornu of the lateral ventricle, and the crus cerebri.

Veins of the Mid-brain.—The veins of the mid-brain terminate for the most part in the veins of Galen.

Cerebellar Veins.—These veins also are divisible into two groups, the superficial and the deep. The former are quite independent of and much more numerous than the arteries. They form two sets, the superior and the inferior.

The **superior superficial cerebellar veins** (vv. cerebelli superiores) terminate in a single median or vermian efferent vessel and in several lateral efferents. The superior vermian vein runs forwards and ends in the vena magna Galeni, and the lateral superior cerebellar veins terminate in the lateral sinuses or in the superior petrosal sinuses.

The **inferior superficial cerebellar veins** (vv. cerebelli inferiores) also form a small vermian and numerous lateral efferents; the former runs backwards and joins either the straight sinus or one of the lateral sinuses, and the latter end in the inferior petrosal and occipital sinuses.

The **deep cerebellar veins** issue from the substance of the cerebellum and terminate in the superficial veins.

Veins of the Pons Varolii.—The deep veins from the substance of the pons pass forwards to its anterior surface, where they become superficial, and, anastomosing together, form a plexus which is drained by superior and inferior efferent veins. The superior efferent veins join the basilar vein; the inferior efferent veins either unite with the cerebellar veins, or they open into the superior petrosal sinus.

Veins of the Medulla Oblongata.—Deep veins of the bulb issue from its substance and end in a superficial plexus. This plexus is drained by an anterior and a posterior median vein and by radicular veins.

The **anterior median vein** is continuous below with the corresponding vein of the spinal cord; it communicates above with the plexus on the surface of the pons.

The **posterior median vein** is continuous below with the posterior median vein of the cord, from which it ascends to the lower end of the fourth ventricle, where it divides into two branches which join the inferior petrosal or basilar sinuses.

The **radicular veins** issue from the lateral parts of the plexus and run with the roots of the last four cranial nerves; they end in the inferior petrosal and occipital sinuses.

Blood Sinuses of the Cranium.

The **venous sinuses** of the cranium are spaces between the layers of the dura mater; they are lined by an endothelium which is continuous with the endothelium of the veins. They receive the veins of the brain, communicate frequently with the meningeal veins and with veins external to the cranium, and terminate directly or indirectly in the internal jugular vein. Some of the cranial blood sinuses are unpaired, others are paired.

Unpaired Sinuses.—These are the superior longitudinal, the inferior longitudinal, the straight, the circular, and the basilar.

The **superior longitudinal sinus** (sinus sagittalis superior) commences in the

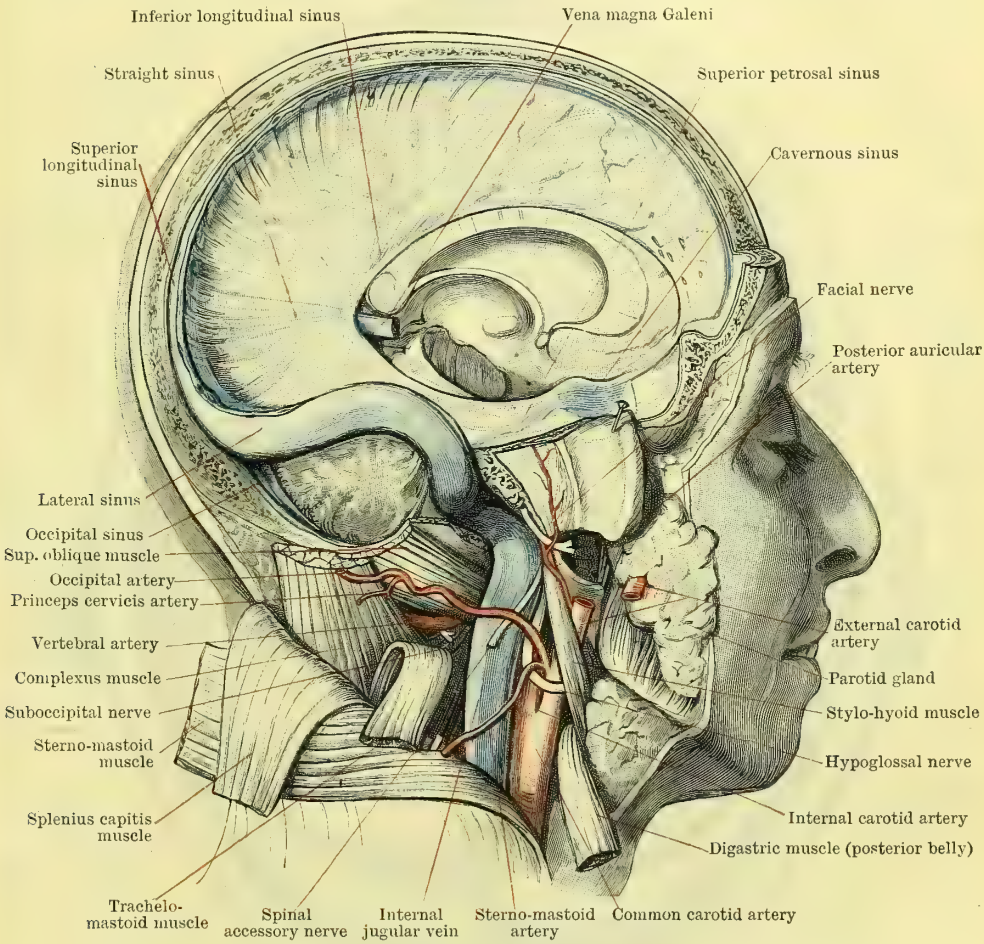


Fig. 582.—Dissection of the Head and Neck, showing the cranial blood sinuses and the upper part of the internal jugular vein.

anterior fossa of the cranium, at the crista galli, where it communicates through the foramen cæcum with the veins of the nasal cavity or with the angular vein. It passes upwards, then backwards, and finally downwards in the convex margin of the falx cerebri, grooving the frontal, parietal, and upper part of the occipital bones. As it descends it passes slightly to the right side, and it ends at the level of the internal occipital protuberance by becoming the right lateral sinus. Instead of passing to the right, it occasionally turns to the left, and ends in the left lateral sinus. In either case its termination is associated with a well-marked dilatation, the *torcular Herophili*, which marks a confluence of sinuses, and which is lodged in a depression at one side of the internal occipital protuberance. The torcular is connected, across the protuberance, by an anastomosing channel with a similar dilatation, which marks the junction of the straight sinus with the lateral sinus of the opposite side.

Opening into the superior longitudinal sinus are the superior cerebral veins, and it communicates on each side by small openings with a series of spaces in the dura mater, the **lacunæ laterales**, into which the Pacchionian bodies (arachnoidal villi) project. It also communicates, by emissary veins which pass through the foramen cæcum and through each parietal foramen (emissarium parietale), with the veins on the exterior of the cranium. Its cavity, which is triangular in transverse section, is crossed by several fibrous strands called the **chordæ Willisii.**

The **inferior longitudinal sinus** (sinus sagittalis inferior) lies in the posterior

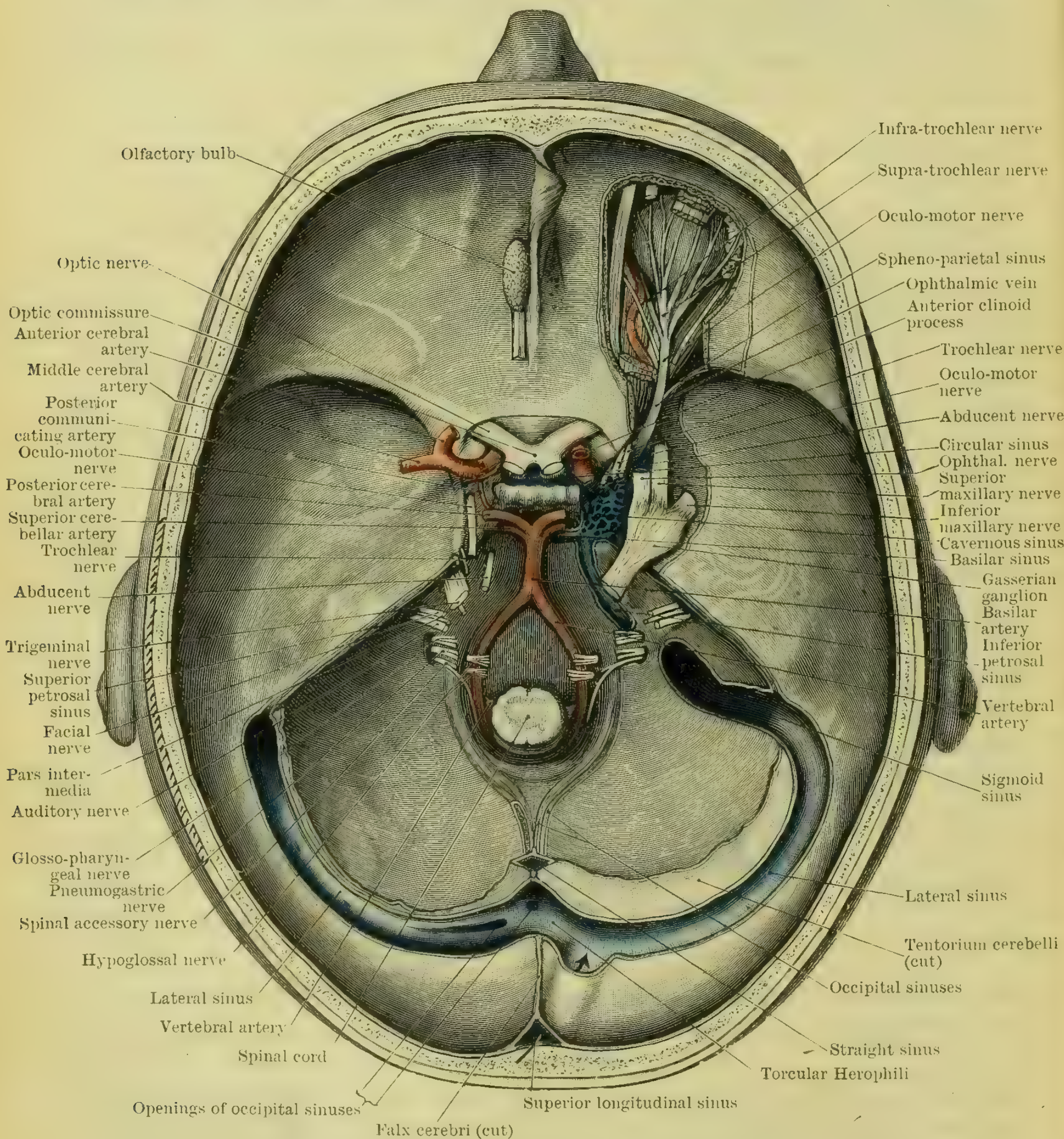


FIG. 583.—BASAL BLOOD SINUSES OF THE DURA MATER.

two-thirds of the lower free margin of the falx cerebri. It terminates posteriorly by joining with the vena magna Galeni to form the straight sinus. It is circular in transverse section, and it receives tributaries from the falx cerebri and from the inner surface of the middle third of each cerebral hemisphere.

The **circular sinus** (sinus circularis) is situated in the pituitary fossa, and surrounds the pituitary body. It is usually formed by anterior (sinus intercavernosus anterior) and posterior (sinus intercavernosus posterior) transverse channels which pass across the pituitary fossa from one cavernous sinus to the other.

The **basilar sinus** (plexus basilaris).—The term basilar sinus is applied to a venous plexus situated in the dura mater on the basilar part of the occipital bone. It connects the posterior ends of the cavernous or the anterior ends of the inferior petrosal sinuses together, and communicates below with the anterior spinal veins.

The **straight sinus** (sinus rectus) is formed by the union of the inferior longitudinal sinus with the great vein of Galen. It runs downwards and backwards, along the line of attachment of the falx cerebri to the tentorium cerebelli. As a general rule it turns to the left at the internal occipital protuberance, dilates somewhat, and becomes continuous with the left lateral sinus, its dilatation being united with the corresponding dilatation on the lower end of the superior longitudinal sinus—the torcular Herophili—by a transverse anastomosing channel. Occasionally the straight sinus terminates in the right lateral sinus, and in that case the superior longitudinal sinus ends in the left lateral sinus. It receives some of the superior cerebellar veins and a few tributaries from the falx cerebri.

Paired Sinuses.—There are six pairs of sinuses—viz. the lateral, the occipital, the cavernous, the superior petrosal, the inferior petrosal, and the spheno-parietal.

Lateral Sinuses.—Each lateral sinus (sinus transversus) commences at the internal occipital protuberance, the right usually as the continuation of the superior longitudinal, and the left as the continuation of the straight sinus. Each passes outwards in the outer border of the tentorium cerebelli and in a groove in the occipital bone. From the lateral angle of the occipital bone it passes on to the posterior inferior angle of the parietal bone, which it grooves; then it leaves the tentorium and turns downwards on the inner surface of the mastoid portion of the temporal bone; from the latter it passes to the upper surface of the jugular process of the occipital bone, and turns forwards and then downwards into the jugular foramen, where it becomes continuous with the internal jugular vein.

Its tributaries are some of the superior and inferior cerebellar veins, a posterior diploic vein, and the superior petrosal sinus. It is connected with the veins outside the cranium by emissary veins which pass through the mastoid and posterior condylar foramina.

The **occipital sinuses** (sinus occipitales) lie in the attached border of the falx cerebelli and in the dura mater along the postero-lateral boundaries of the foramen magnum; frequently they unite above and open by a single channel into the commencement of either the right or the left lateral sinus, but their upper extremities may remain separate, and then each communicates with the commencement of the lateral sinus of its own side. They open below into the terminal part of the corresponding lateral sinuses, and they communicate with the posterior spinal veins. Each occipital sinus is an anastomosing channel between the upper and lower extremities of the lateral sinus of the same side, and each receives a few inferior cerebellar veins.

The **cavernous sinuses** lie at the sides of the body of the sphenoid bone. Each sinus (sinus cavernosus) commences anteriorly at the inner end of the sphenoidal fissure, where it receives the corresponding ophthalmic vein, and it terminates at the apex of the petrous portion of the temporal bone by dividing into the superior and the inferior petrosal sinuses. Its cavity, which is irregular in size and shape, is so divided by numerous fibrous strands that it assumes the appearance of cavernous tissue, and in its outer wall are embedded the internal carotid artery with its sympathetic plexuses, the third, fourth, first and second divisions of the fifth, and the sixth cranial nerves. Its tributaries are the spheno-parietal sinus and the inferior cerebral veins, including the superficial Sylvian vein. It communicates with the opposite cavernous sinus by means of the circular sinus; with the pterygoid plexus in the zygomatic fossa by an emissary vein which passes either through the foramen ovale or through the foramen Vesalii; with the internal jugular vein by small venous channels which accompany the internal carotid artery through the carotid canal, and by the inferior petrosal sinus; with the lateral sinus by the superior petrosal sinus, and through the ophthalmic vein with the angular vein.

The **spheno-parietal sinuses** (s. spheno-parietales) are lodged in the dura mater on the under surfaces of the small wings of the sphenoid bone close to their posterior

borders. Each sinus communicates with the middle meningeal veins, receives veins from the dura mater, and terminates in the anterior part of the corresponding cavernous sinus.

Superior Petrosal Sinuses.—Each superior petrosal sinus (s. petrosus superior) commences at the apex of the petrous portion of the temporal bone in the posterior end of the corresponding cavernous sinus. It runs backwards and outwards in the attached margin of the tentorium cerebelli, above the fifth cranial nerve, and grooves the upper border of the petrous portion of the temporal bone, at the outer extremity of which it terminates in the lateral sinus at the point where the latter is turning downwards on the inner surface of the mastoid portion of the temporal bone. It receives inferior cerebral, superior cerebellar, tympanic, and diploic veins.

Inferior Petrosal Sinuses.—An inferior petrosal sinus (s. petrosus inferior) commences at the posterior end of each cavernous sinus; it runs backwards, outwards, and downwards in the posterior fossa of the cranium, in a groove along the lower margin of the petrous portion of the temporal bone and the adjacent border of the basilar portion of the occipital bone, to the anterior compartment of the jugular foramen of the same side, through which it passes. It crosses the last four cranial nerves either externally or internally, and it terminates in the internal jugular vein. Its tributaries include inferior cerebellar veins and veins from the internal ear, which pass to it through the internal auditory meatus, the aqueductus cochlea, and the aqueductus vestibuli.

THE SPINAL VEINS.

The spinal veins include—

(1) The extra-spinal veins.
  (*a*) The anterior spinal plexus.
  (*b*) ,, posterior ,,
(2) The veins of the bodies of the vertebræ.
(3) The intra-spinal veins.
  (*a*) The anterior longitudinal veins.
  (*b*) ,, posterior ,, ,,
(4) The veins of the spinal cord.

The **anterior spinal plexus** lies in front of the bodies of the vertebræ. It consists of a number of relatively small anastomosing channels, which communicate with the veins of the bodies of the vertebræ, and which receive tributaries from the adjacent muscles and ligaments. Its efferent vessels terminate in the cervical region in the anterior deep cervical vein, in the dorsal region in intercostal veins, in the lumbar region in the lumbar veins, and in the sacral region in the lateral sacral veins.

The **posterior spinal plexus** consists of numerous anastomosing venous channels which lie on the laminæ and round the spines and the articular and transverse processes of the vertebræ. The plexus receives tributaries from the muscles and skin of the back, and communicates, through the ligamenta subflava, with the posterior longitudinal spinal veins in the interior of the spinal canal. Its efferent vessels pass between the transverse processes of the vertebræ, or through the sacral foramina, and terminate in the vertebral, the intercostal, the lumbar, and the lateral sacral veins respectively.

Veins of the Bodies of the Vertebræ.—The cancellous tissue of the bodies of the vertebræ is permeated by large venous channels which communicate anteriorly with the anterior spinal plexus. These channels terminate posteriorly in the *venæ basis vertebræ*, which open into transverse anastomosing vessels which connect the anterior longitudinal spinal veins.

Anterior Longitudinal Spinal Veins.—Two anterior longitudinal spinal veins collect blood from the bodies of the vertebræ, from the adjacent ligaments, and from the spinal dura mater. They are plexiform vessels which extend from the foramen magnum, behind the bodies of the vertebræ and along the margins of the posterior common ligament, to the coccyx, and they are connected together, opposite each vertebral body, by transverse anastomoses which lie between the posterior common ligament and the bodies of the vertebræ; these transverse anastomoses are greatly dilated opposite the centres of the bodies where they receive the venæ basis vertebræ. Each anterior longitudinal spinal vein communicates round the margin of the canal with the corresponding posterior vein,

and it gives off efferent vessels which pass through the intervertebral foramina to terminate, according to the region in which they are placed, in the vertebral, intercostal, lumbar, or lateral sacral veins.

Superiorly the anterior longitudinal spinal veins give off large offsets, above the arch of the atlas, which form the commencement of the vertebral veins; through the foramen magnum they communicate with the basilar and with the occipital sinuses.

The **posterior longitudinal spinal veins** are placed, one on each side, between the dura mater anteriorly and the laminæ and ligamenta subflava posteriorly. They are plexiform vessels which extend along the whole length of the spinal canal. They receive tributaries from the laminæ, ligaments, and spinal membranes, and from a post-vertebral plexus of veins which lies between the laminæ of the vertebræ and the deep muscles of the back; they anastomose with each other by transverse channels which pass across the laminæ, with the posterior spinal plexus by vessels which pierce the ligamenta subflava, and with the anterior longitudinal veins round the margins of the canal. Their efferent vessels unite with those of the anterior longitudinal veins, and terminate with them.

By means of the longitudinal spinal veins and the anastomoses between them, a venous ring is formed within the spinal canal opposite each vertebra. Commencing in front, opposite the body of the vertebra, where it receives the vena basis vertebra, it passes outwards to the anterior longitudinal spinal vein, turns backwards along the inner side of the pedicle and the inner surface of the lamina to the posterior longitudinal vein, and is completed by the anastomosis between the posterior longitudinal veins. This ring communicates through the ligamenta subflava with the posterior spinal plexus, and through the intervertebral foramina with the vertebral, with the dorsal tributaries of the intercostal or lumbar veins, or with the lateral sacral veins, according to the region in which it lies.

Superiorly the posterior longitudinal spinal veins communicate with the occipital sinuses, and as these also communicate with the anterior spinal veins, and the latter with the basilar sinus, a venous ring is completed round the foramen magnum.

Veins of the Spinal Cord.—The veins of the spinal cord issue from the substance of the cord, and terminate in a plexus in the pia mater. In this plexus there are six longitudinal channels—one *antero-median*, along the anterior fissure, two *antero-lateral*, immediately behind the anterior nerve roots, two *postero-lateral*, immediately behind the posterior nerve roots, and one *postero-median*, over the postero-septum. Radicular efferent vessels issue from the plexus, and pass along the nerve roots to communicate with the efferent vessels from the anterior and posterior longitudinal spinal veins, and to terminate in them. The veins of the spinal cord vary very much in size, but they are largest on the lower and on the posterior portions of the cord.

The postero-median and antero-median veins are continued above into the corresponding veins of the medulla oblongata.

The antero-lateral and postero-lateral veins pour their blood partly into the median veins and partly into the radicular veins; indeed, the greater part of the blood from the spinal cord is returned by the latter veins.

THE VEINS OF THE UPPER EXTREMITY.

The veins of each upper extremity are divisible into two sets—viz. **superficial** and **deep**. Both sets open eventually into a common terminal trunk which is known as the **axillary vein**. This vein is therefore the chief efferent stem of the upper extremity. It is continued as the subclavian vein to the innominate vein, and its blood, together with that of the corresponding side of the head and neck, reaches the superior vena cava.

The Deep Veins of the Upper Extremity.

The deep veins, with the exception of the axillary vein, are arranged in pairs which accompany the different arteries and are similarly named. So far as these veins (venæ comites) are concerned it will be sufficient to state that they are provided with several valves, that they are situated one on either side of the artery with which they are associated, and that they are usually united together by

numerous transverse anastomoses which cross in front of or behind the artery. The axillary vein, however, requires more detailed consideration.

The Axillary Vein.

The **axillary vein** (v. axillaris, Fig. 561) commences, as the direct continuation of the basilic vein, opposite the lower border of the teres major. It passes upwards and inwards through the axilla, along the inner side of the corresponding artery, and terminates at the outer border of the first rib by becoming the subclavian vein. It possesses a bicuspid valve which is usually situated opposite the lower border of the subscapularis muscle.

Relations.—Its anterior relations are similar to those of the axillary artery, but, in addition, the vein is crossed in front, under cover of the clavicular part of the pectoralis major, by the pectoral branches of the acromio - thoracic artery, and by branches of the internal anterior thoracic nerve, and it receives in front, just above the upper border of the pectoralis minor, the termination of the cephalic vein.

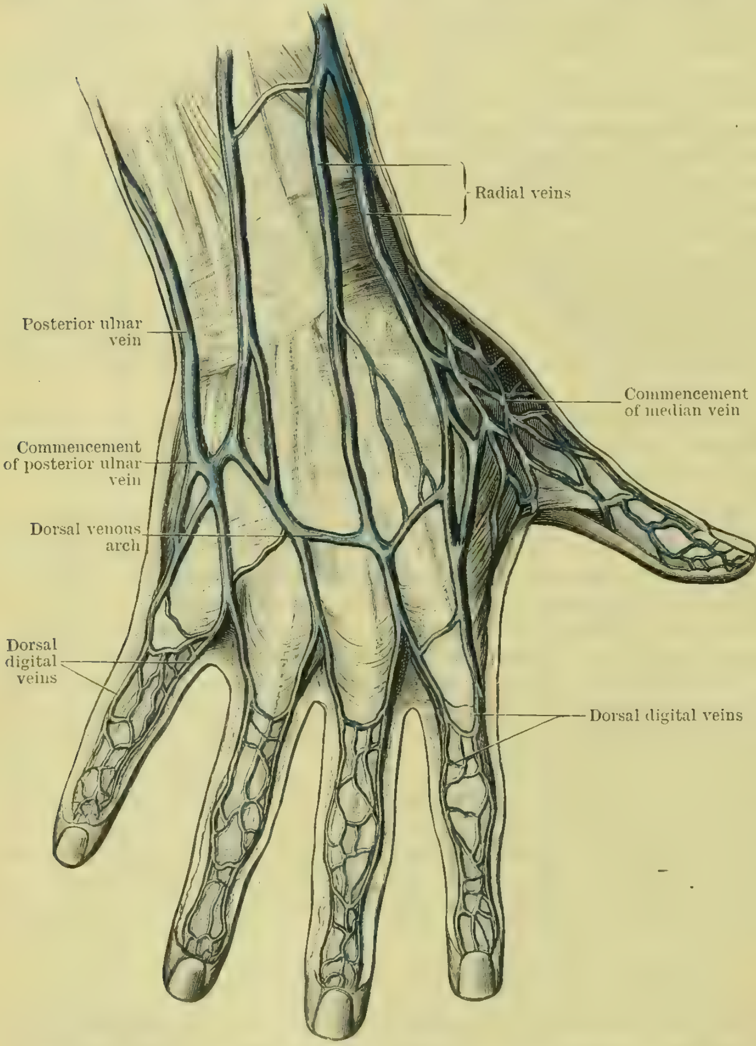


Fig. 584.—Superficial Veins on the Dorsum of the Hand and Digits.

Behind it are the muscles which form the posterior wall of the axilla, the axillary fat, and the first serration of the serratus magnus. The long thoracic nerve intervenes between it and the serratus magnus, and the subscapular nerves and the subscapular artery pass between it and the subscapularis.

It is separated from the axillary artery on the outer side, in the lower part of its extent by the ulnar and internal cutaneous nerves, in the middle of its course by the inner cord of the brachial plexus, and in the upper part of the axilla, behind the costo-coracoid membrane, by the internal anterior thoracic nerve. To its inner side lie the outer set of axillary glands, and in the lower part of the axilla the lesser internal cutaneous nerve.

Tributaries.—In addition to tributaries corresponding with the branches of the axillary artery, it receives the venæ comites of the brachial artery, at the lower border of the subscapularis, and the cephalic vein, which joins it at the upper border of the small pectoral muscle.

The Superficial Veins of the Upper Extremity.

The superficial veins of the upper extremity commence in the superficial fascia of the palm and dorsum of the hand and of the fingers.

The superficial veins of the palmar aspects of the fingers terminate for the most part in **dorsal digital veins,** which run along the dorso-lateral borders of the digits; some, however, pass upwards into the palm and join the superficial palmar veins, which, in comparison with the superficial dorsal veins, are relatively few and small. The superficial veins of the palm anastomose together, forming a more or less polygonal plexus from which some efferent vessels pass laterally round the borders of the palm to the dorsal plexus of the hand, whilst others ascend towards the wrist, where they end either in the median or the anterior ulnar superficial veins of the forearm.

The superficial veins on the dorsal aspect of each digit form two longitudinal vessels, the **dorsal digital veins** (vv. digitales dorsales propriæ), which ascend along the dorso-lateral borders of the digit. They receive tributaries from the palmar aspect of the digit, from the pulp of the tip, from the subungual tissues, and from the superficial tissues of the dorsum. The dorsal digital veins, which run along the adjacent borders of the second, third, and fourth interdigital clefts, unite, at the apices of the clefts, to form three **dorsal interosseous** or **interdigital veins** (vv. metacarpæ dorsales), which terminate on the dorsum of the hand in a dorsal venous arch or dorsal venous plexus; the radial or outer vein of the index-finger ends in the same arch.

The **dorsal venous arch** of the hand receives not only the dorsal interosseous or interdigital veins, and the radial digital vein of the index-finger, but also numerous tributaries from the superficial tissues of the dorsum of the hand, which anastomose frequently together and form a plexiform network. The arch lies opposite the lower parts of the shafts of the four inner metacarpal bones, and terminates at its radial end in the superficial radial vein, and at its ulnar end in the posterior or dorsal ulnar vein; the dorsal digital veins of the thumb open into the superficial radial vein, and the innermost or ulnar digital vein of the little finger ends in the posterior superficial ulnar vein.

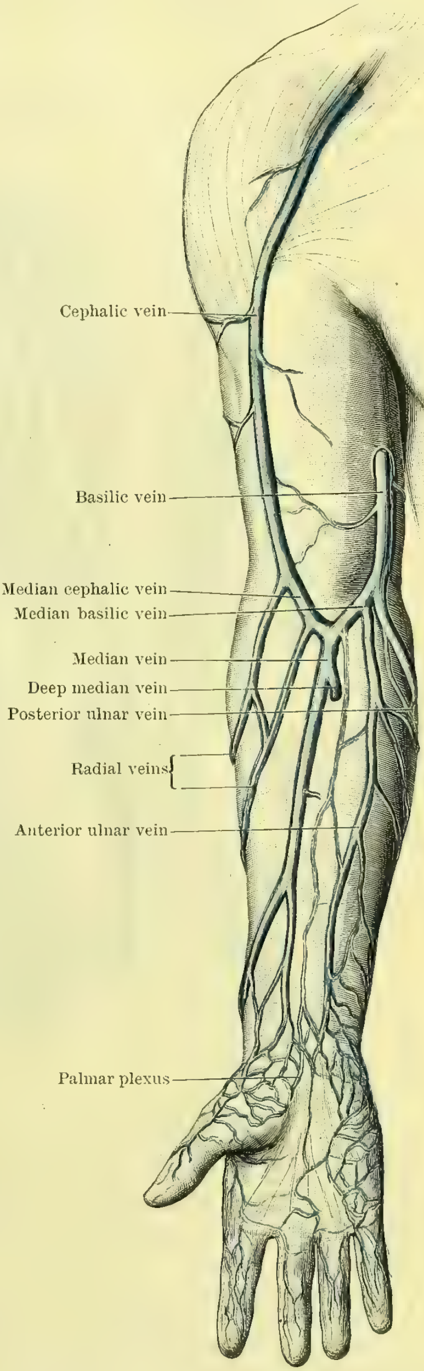


Fig. 585.—Superficial Veins on the Flexor Aspect of the Upper Extremity.

Superficial Veins of the Forearm.—There are four main superficial venous trunks in the forearm—viz. the median, the radial, and the anterior and posterior ulnar veins.

The **median vein** (v. mediana cubiti) commences, as a rule, on the dorsal aspect of the base of the thumb by the union of a number of efferents from the dorsal plexus; it turns round the radial border of the forearm, receives numerous tributaries from the radial and median portions of the palm, and ascends to the middle of the bend of the elbow, where it is joined by the *deep median vein*, a large anastomosing channel which connects it with the deep veins, and immediately afterwards terminates by dividing into median cephalic and median basilic branches.

The **median cephalic** (v. mediana cephalica), or outer branch of the median vein, runs upwards and outwards in the groove between the biceps and the supinator longus muscles. It crosses the musculo-cutaneous nerve superficially, and terminates, a short distance above the external condyle, by uniting with the radial vein to form the cephalic vein.

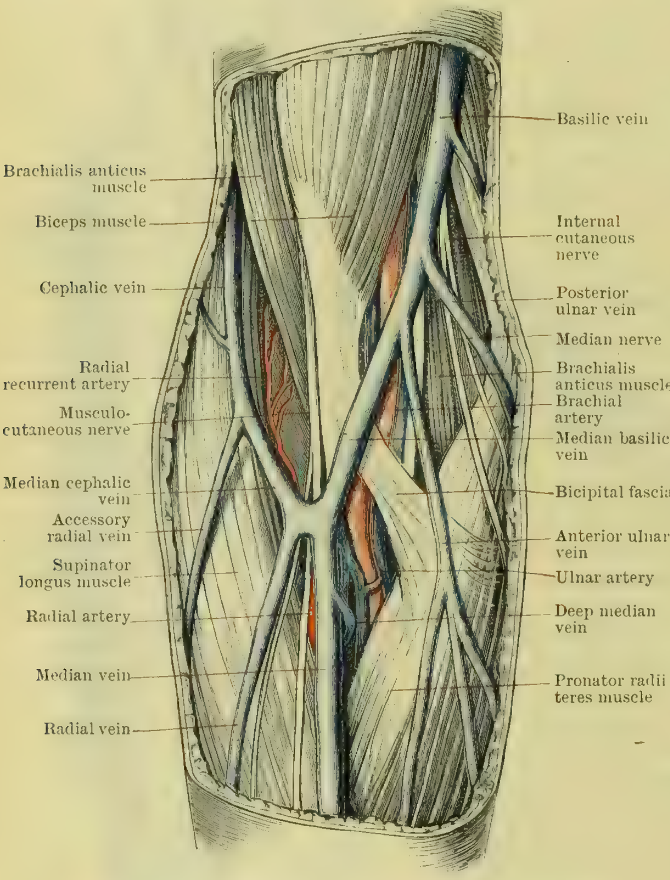


FIG. 586.—SUPERFICIAL VEINS AT THE BEND OF THE ELBOW.

The **median basilic vein** (v. mediana basilica) is the inner branch of the median vein. Running more transversely than the median cephalic vein, it passes upwards and inwards along the groove between the biceps and the pronator radii teres. It is crossed superficially by the anterior terminal branch of the internal cutaneous nerve; it lies upon the bicipital fascia, which separates it from the brachial artery, and it terminates by uniting with the anterior and posterior ulnar veins to form the basilic vein.

The **radial vein** (v. radialis) commences in the dorsal venous plexus of the hand, and, after receiving some of the dorsal digital veins of the thumb, runs up the radial border of the forearm in relation with the anterior division of the musculo-cutaneous nerve. It receives tributaries from the subcutaneous tissue through which it passes, and terminates at the outer side of the bend of the elbow by uniting with the median cephalic branch of the median vein to form the cephalic vein. It contains several valves.

The **anterior** and **posterior ulnar veins** (vv. ulnares) vary considerably in size, but as a rule the posterior is the larger. Both are provided with valves.

The **anterior ulnar vein** commences at the base of the little finger, by the union of tributaries from the ulnar part of the dorsal venous plexus and from the ulnar side of the palm; it ascends along the front of the ulnar side of the forearm, and it terminates in the basilic branch of the median vein.

The **posterior ulnar vein** commences in the dorsal venous plexus; it receives the ulnar dorsal digital vein of the little finger, and ascends along the dorsal side of the ulnar aspect of the forearm. It terminates by joining the basilic branch of the median vein to form the basilic vein.

Superficial Veins of the Upper Arm.—Only two large superficial trunks, the basilic and the cephalic, are found in the upper arm.

The **basilic vein** (v. basilica) commences at the upper and inner part of the bend of the elbow by the union of the median basilic with the posterior ulnar vein. It ascends in a groove along the inner border of the biceps to the middle of the upper arm, where it passes through an opening in the deep fascia, the hiatus semilunaris, and in the rest of its course lies deeply along the inner side of the brachial artery. It terminates at the lower border of the teres major by becoming the axillary vein, and it contains one or more bicuspid valves.

The **cephalic vein** (v. cephalica) is formed at the upper and outer part of the bend of the elbow by the union of the radial vein with the cephalic branch of the median vein. It ascends first along the outer border of the biceps, where it is accompanied by the superior external cutaneous branch of the musculo-spiral nerve; then, after piercing the deep fascia, it is continued upwards between the adjacent borders of the deltoid and pectoralis major muscles, accompanied by the descending or humeral branch of the acromio-thoracic axis. Just below the clavicle it turns inwards, pierces the costo-coracoid membrane, and terminates in the upper or third part of the axillary vein. It is provided with a bicuspid valve at its termination. In its primitive form it terminated in the external jugular vein, to reach which it passed either over or through the clavicle. This condition occasionally persists, or is represented by a small communicating vein.

THE INFERIOR VENA CAVA AND ITS TRIBUTARIES.

The **inferior vena cava** (Fig. 587) is a large venous trunk which receives the whole of the blood from the lower extremities, and the greater part of the blood from the walls and contents of the abdomen and pelvis. It commences opposite the right side of the body of the fifth lumbar vertebra, behind and to the right of the right common iliac artery, ascends through the abdomen in front and to the right of the vertebral column and the right crus of the diaphragm, and pierces the cupola of the diaphragm, between the middle and right sections of the central tendinous leaflet, at the level of the eighth dorsal vertebra. It then enters the middle mediastinum, passes through the pericardium, and terminates in the lower and back part of the right auricle. Its intrapericardial portion is very short, and it is covered on its anterior and lateral aspects by the parietal portion of the serous layer. Attached to the lower and front margin of its auricular orifice is the Eustachian valve, which is a remnant of an important fold of endocardium by which, in the fœtus, the blood from the inferior vena cava is directed, through the foramen ovale, into the left auricle.

Relations.—The inferior vena cava is in relation behind with the bodies of the lower lumbar vertebræ and the corresponding part of the anterior common ligament, the anterior portion of the right psoas muscle, the right lumbar sympathetic cord, the roots of the right lumbar arteries, the right crus of the diaphragm, the right renal artery, the right semilunar ganglion, the right inferior phrenic artery, and the inner and upper portion of the right suprarenal body.

In front of it, from below upwards, are the following structures—the right common iliac artery, the lower end of the mesentery and the superior mesenteric artery, the spermatic artery and the third part of the duodenum, the head of the pancreas, the portal vein and the first part of the duodenum, the foramen of Winslow, and the posterior surface of the liver. More superficially are coils of small intestine, the great omentum, and the transverse colon and mesocolon.

To its left side are the aorta and the right crus of the diaphragm.

On its right side and below is the right ureter, whilst at a higher level the right kidney is only separated from it by a short interval.

Tributaries.—In addition to the two common iliac veins, by the union of which it is formed, and through which it receives blood from the pelvis and from the lower extremities, the inferior vena cava receives the following tributaries:—The hepatic veins, the right inferior phrenic vein, the right suprarenal vein, the right and left renal veins, the right spermatic or ovarian vein, and the right and left lumbar veins.

Hepatic Veins (vv. hepaticæ, Fig. 587).—These veins convey blood which has passed through the liver from the portal veins and from the hepatic artery; they open into that portion of the inferior vena cava which lies immediately below the diaphragm, and behind the right lobe of the liver. They form two groups, an upper consisting of two or three large trunks, and a lower group of smaller veins.

The upper group occasionally consists of only two veins, a right and a left;

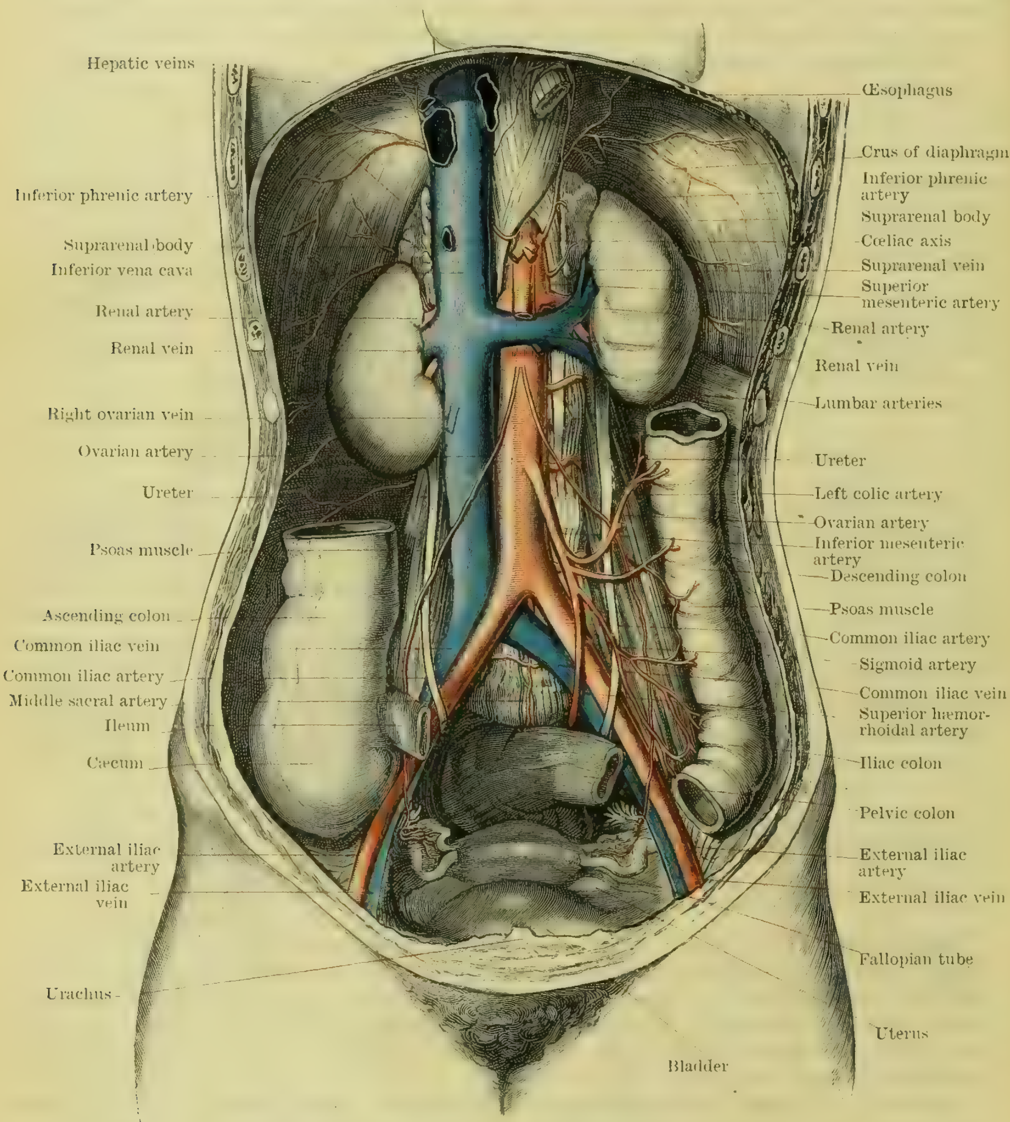


FIG. 587.—THE INFERIOR VENA CAVA AND ITS TRIBUTARIES.

more frequently there are three vessels, a right, a left, and a middle vein, and in the latter case the middle vein issues from the Spigelian lobe.

The veins of the lower group vary in number from six or seven to twenty; they return blood from the right and Spigelian lobes.

The hepatic veins commence in the interior of the lobules of the liver as *intralobular veins;* these issue from the upper and posterior aspects of the lobules, and unite together to form *sublobular veins;* and the latter, uniting with one another as they converge towards the posterior surface of the liver, form the larger hepatic veins.

Inferior Phrenic Veins (vv. phrenicæ inferiores).—The venæ comites of

the inferior phrenic arteries are formed by tributaries which issue from the substance of the diaphragm. The right vein terminates in the upper part of the inferior vena cava. The left veins pass behind the œsophagus, and usually end in the left suprarenal vein.

Suprarenal Veins.—A single suprarenal vein (v. suprarenalis) issues from the hilus on the anterior surface of each suprarenal body; the right vein terminates in the inferior vena cava; the left usually ends in the left renal vein, but sometimes also opens directly into the inferior vena cava.

Renal Veins (vv. renales).—Each renal vein is formed by the union of five or six tributaries which issue from the hilus of the kidney, where they lie in front of the corresponding arteries.

The **right renal vein** is about one inch long; it passes behind the second part of the duodenum, and terminates in the right side of the inferior vena cava.

The **left renal vein** crosses in front of the left psoas, the left crus of the diaphragm, and the aorta immediately below the superior mesenteric artery. It lies behind the pancreas and the fourth part of the duodenum, and, running above the third part of the duodenum, terminates in the left side of the inferior vena cava. The left spermatic or ovarian vein, according to the sex, and almost invariably the left suprarenal vein, open into it.

Lumbar Veins (vv. lumbales).—There are usually four lumbar veins on each side, one with each lumbar artery; the vein with the subcostal artery is not included in this number. The lumbar veins are formed by the union of anterior and posterior trunks between the transverse processes of the vertebræ. The anterior tributaries commence in the lateral walls of the abdominal cavity, where they communicate with the superior and deep epigastric veins. The posterior tributaries issue from the muscles of the back in the lumbar region, and receive tributaries from the spinal plexuses. The main stems pass forwards on the bodies of the vertebræ; on each side they run under the psoas muscle, whilst those of the left side also pass behind the aorta. They terminate in the posterior part of the inferior vena cava. Not uncommonly the corresponding veins of opposite sides unite together to form a single trunk which enters the back of the inferior vena cava. All the lumbar veins of each side are united together by a longitudinal anastomosing vessel, the ascending lumbar vein, which passes upwards in front of the transverse processes of the lumbar vertebræ, and usually ends above in an azygos vein, whilst below it connects the lumbar veins with the ilio-lumbar and lateral sacral veins.

Spermatic Veins (vv. spermaticæ).—The spermatic veins on each side issue from the testicle and epididymis and form a plexus, the *pampiniform plexus.* The plexus forms part of the spermatic cord, and consists of from eight to ten veins, most of which lie in front of the vas deferens; it passes upwards in the inguinal canal, and, near the internal abdominal ring, terminates in two main trunks which ascend with the corresponding spermatic artery for some distance, receiving tributaries from the ureter, and on the left side from the iliac and pelvic colon; ultimately the two veins unite together and a single terminal vein is formed. The terminal spermatic vein on the right side opens into the inferior vena cava, that on the left side into the left renal vein. The left spermatic veins are longer than the right, the left testicle being lower than the right, and the termination in the left renal vein being at a higher level than the termination of the right vein in the inferior vena cava. The spermatic veins on each side lie upon the psoas muscle and the ureter. They are covered by peritoneum, and they are crossed on the right side by the termination of the ileum and the third part of the duodenum, and on the left side by the iliac colon. They are provided with valves both in their course and at their terminations, but occasionally the valve at the orifice of the left spermatic vein is absent.

The **ovarian veins** (vv. ovaricæ), on each side, issue from the hilus on the anterior border of the ovary. They pass between the layers of the broad ligament, where they anastomose freely and form the *pampiniform plexus,* which extends outwards towards the brim of the pelvis. From the plexus two veins are formed which accompany the corresponding ovarian artery; they pass in front of the external

iliac artery, and then upwards behind the peritoneum and in front of the psoas muscle and ureter. The veins of the right side, like the corresponding spermatic veins, also pass behind the termination of the ileum and the third part of the duodenum; whilst the left veins, near the brim of the pelvis, pass behind the commencement of the pelvic colon.

The two veins on each side ultimately fuse together to form a single terminal vein which ends, on the right side in the inferior vena cava, and on the left side in the left renal vein. As the left ovarian veins ascend on the psoas they receive tributaries from the iliac and pelvic colon.

The Iliac Veins.

The **common iliac veins** (Figs. 572 and 587), right and left, are formed by the union of the corresponding external and internal iliac veins. Each commences opposite the brim of the pelvis, immediately behind the upper part of the internal iliac artery of its own side, and both vessels pass upwards to the right side of the body of the fifth lumbar vertebra, at the upper part of which, just behind and to the outer side of the right common iliac artery, they unite together to form the inferior vena cava.

The **right common iliac vein** (v. iliaca communis dextra) is much shorter than the left; it passes in front of the obturator nerve and the ilio-lumbar artery, and at first behind and then somewhat to the outer side of the corresponding common iliac artery.

The **left common iliac vein** (v. iliaca communis sinistra) is much longer than the right, and is also placed more obliquely. It passes upwards and to the right, in front of the body of the fifth lumbar vertebra, and across the middle sacral artery. For some distance it runs along the inner side of the left common iliac artery, and then passes behind the right common iliac artery. It also passes behind the mesentery of the pelvic colon and the superior hæmorrhoidal artery.

Tributaries.—Each common iliac vein receives the corresponding external and internal iliac veins and the ilio-lumbar vein. The left common iliac vein receives in addition the middle sacral vein.

The **ilio-lumbar veins** (vv. ilio-lumbales) receive tributaries from the iliac fossa, from the lower parts of the spinal muscles, and from the spinal canal. There is a single vein on each side which accompanies the corresponding artery. It passes behind the psoas muscle and terminates in the common iliac vein.

Middle Sacral Veins.—The venæ comites of the middle sacral artery commence by the union of tributaries which issue from the venous plexus in front of the sacrum, through which they communicate with the lateral sacral veins and receive blood from the sacral part of the spinal canal. They unite above into a single stem (v. sacralis media), which terminates in the left common iliac vein.

The **internal iliac vein** (v. hypogastrica, Fig. 569) is a short trunk formed by the union of tributaries which correspond to all the branches of the internal iliac artery, with the exception of the hypogastric or umbilical branch.

It commences at the upper border of the great sciatic notch, and ascends to the brim of the pelvis, where it unites with the external iliac vein to form the common iliac vein. It lies immediately behind and slightly to the inner side of the internal iliac artery, is crossed externally by the obturator nerve, and is in relation internally, on the left side with the pelvic colon, and on the right side with the lower part of the ileum.

Tributaries.—The tributaries, which are numerous, are conveniently divisible into extra-pelvic and intra-pelvic groups.

The *extra-pelvic tributaries* are all **parietal**, and include the obturator, internal pudic, sciatic, and gluteal veins.

Obturator Vein (v. obturatoria).—This vein is formed by the union of tributaries which issue from the hip-joint and from the muscles on the upper and inner part of the thigh. It enters the pelvis through the obturator foramen, runs backwards along the lateral wall lying on the pelvic fascia immediately below the corresponding artery, and, passing between the internal iliac artery on the outside and the ureter on the inside, terminates in the internal iliac vein.

Sciatic Veins (vv. glutaeæ inferiores).—The venæ comites of the sciatic artery commence in the subcutaneous tissues on the back of the thigh; they ascend with the sciatic artery, and pass deeply into the buttock beneath the gluteus maximus, where they receive numerous tributaries from the surrounding muscles. Entering the pelvis through the great sciatic foramen, they unite into a single vessel, which terminates in the lower and anterior part of the internal iliac vein below the termination of the obturator vein.

Gluteal Veins (vv. glutaeæ superiores).—The venæ comites of the gluteal artery are formed by tributaries which issue from the muscles of the buttock. They accompany the artery through the great sciatic foramen, and terminate in the internal iliac vein; they frequently unite together before reaching their termination.

Internal Pudic Veins.—The venæ comites of the internal pudic artery commence by tributaries which emerge from the corpus cavernosum of the penis (vv. profundæ penis) or clitoris (vv. profundæ clitoridis). They follow the course of the internal pudic artery, and usually join together into a single vessel (v. pudenda interna) which terminates in the internal iliac vein. As tributaries they receive the veins from the bulb, the superficial perineal and inferior hæmorrhoidal veins (vv. hæmorrhoidales inferiores), and veins from the muscles of the buttock.

The **inferior hæmorrhoidal veins**, which commence in the substance of the external sphincter of the anus and in the walls of the anal canal, anastomose with the middle and superior hæmorrhoidal veins, and consequently connect the portal and vena caval systems together.

The *intra-pelvic tributaries* of the internal iliac vein are either (*a*) **parietal** or (*b*) **visceral**; the former comprises the lateral sacral veins, the latter includes the efferent vessels from the plexuses around the several pelvic viscera.

(*a*) **Parietal: Lateral sacral veins** (vv. sacrales laterales) accompany the corresponding arteries, and terminate on each side in the inner and back part of the internal iliac vein.

(*b*) **Visceral tributaries** are derived from the rectum and from the plexuses associated with the uterus, vagina, bladder, and prostate. They include the middle hæmorrhoidal, the uterine, the vaginal, and the vesical veins.

The **middle hæmorrhoidal veins** (vv. hæmorrhoidales mediales) are very irregular; sometimes they cannot be distinguished. When present they are formed by tributaries which commence in the submucous tissue of the rectum, where they communicate with the superior and inferior hæmorrhoidal veins; they pass through the muscular coat, and fuse together to form two middle hæmorrhoidal veins, right and left, each of which runs outwards beneath the peritoneum, on the upper surface of the levator ani, to terminate in the internal iliac vein. In the male each middle hæmorrhoidal vein receives tributaries from the seminal vesicle and vas deferens of its own side.

Uterine Plexuses and Veins.—The **uterine plexuses** lie along the lateral borders of the uterus; they receive tributaries, which are entirely devoid of valves, from the uterus, and they communicate above with the ovarian, and below with the vaginal plexuses.

The **uterine veins** (vv. uterinæ), usually two on each side, issue from the lower parts of the uterine plexuses above their communications with the vaginal plexuses. At first the uterine veins on each side lie in the inner part of the base of the broad ligament above the lateral fornix of the vagina and the ureter; they then pass backwards, accompanying the corresponding artery, in a fold of peritoneum which lies between the back of the broad ligament and the recto-uterine fold; finally they ascend in the floor of the ovarian fossa, and terminate in the internal iliac vein.

Vaginal Plexuses and Vaginal Veins.—The **vaginal plexuses** lie at the sides of the vagina. They receive tributaries from the walls of the vagina, and communicate above with the uterine plexuses, below with the veins of the bulb, in front with the vesical plexus, and behind with the veins which issue from the middle and lower parts of the hæmorrhoidal plexus. A single **vaginal vein** issues from the upper part of the vaginal plexus on each side; it accompanies the corresponding arteries, and terminates in the internal iliac vein.

Superior Vesical Plexus.—The superior vesical plexus of veins lies on the outer surface of the muscular coat of the bladder at the fundus and the sides. It receives tributaries from the mucous and muscular walls, and its efferent vessels terminate in the prostatico-vesical plexus in the male, and in the inferior vesical plexus in the female.

Prostatico-vesical Plexus.—This plexus is distributed round the prostate and the neck of the bladder, and is enclosed between the proper fibrous capsule of the prostate and its sheath of recto-vesical fascia. In front it receives the dorsal vein of the penis, which

usually terminates by two branches; behind and above it communicates with the vesical plexus, and receives tributaries from the seminal vesicles and vasa deferentia. One or more efferent vessels pass from it on each side and open into the corresponding internal iliac vein.

The **inferior vesical plexus** of the female, which represents the prostatico-vesical plexus of the male, surrounds the upper part of the urethra and the neck of the bladder. It receives the dorsal vein of the clitoris, and its efferent vessels terminate in the internal iliac vein.

Dorsal Veins of the Penis (vv. dorsales penis).—There are two dorsal veins of the penis—the superficial and the deep.

The **superficial dorsal vein** receives tributaries from the prepuce, and runs backwards immediately beneath the skin to the symphysis, where it divides into two branches which terminate in the superficial external pudic veins.

The **deep dorsal vein** lies on the dorsum of the penis beneath the deep fascia. It commences in the sulcus behind the glans, by the union of numerous tributaries from the glans and the anterior parts of the corpora cavernosa, and runs backwards in the mid-dorsal line, in the sulcus between the corpora cavernosa, from which it receives many additional tributaries. At the root of the penis the vein passes between the two layers of the suspensory ligament, and then between the subpubic ligament and the deep transverse ligament of the perineum, thus reaching the space between the two layers of the triangular ligament, where it lies above the membranous part of the urethra, and is enclosed in some of the fibres of the compressor urethræ. Passing through the posterior layer of the triangular ligament, it enters the pelvis, and terminates, usually by two branches, in the prostatico-vesical plexus.

The **dorsal vein of the clitoris** in the female has a similar course to that of the deep dorsal vein of the penis in the male. It terminates in the inferior vesical plexus.

THE VEINS OF THE LOWER EXTREMITY.

The veins of the lower extremity, like those of the upper extremity, are arranged in two groups, the **superficial** and the **deep**, and in the lower as in the upper limb the deep veins are associated with the arteries as venæ comites, whilst the superficial veins, which lie in the subcutaneous tissues, ultimately terminate in the deep veins. There is, therefore, a general similarity in the arrangement of the veins of the upper and the lower limbs, but there are differences in the details of the arrangement which are of some importance. Thus in the upper extremity there are two deep veins with each artery from the fingers to the root of the limb, where a single trunk, the axillary vein, is formed; but in the lower extremity each main artery has two venæ comites only as far as the middle of the limb, where a single trunk is formed. This vessel, the **popliteal vein**, is the commencement of the main venous stem of the lower extremity; it is continued upwards through the thigh as the **femoral vein**, and along the brim of the pelvis as the **external iliac vein**, which terminates by uniting with the internal iliac vein to form the common iliac vein.

Further, the superficial veins of the upper limb are more numerous than those of the lower limb, for in the forearm there are four main superficial veins, and in the leg two; in the arm two main superficial veins, and in the thigh only one.

In the upper limb the blood which passes through the superficial veins is poured into the efferent trunk vein at the root of the limb, that is, into the axillary vein; but in the lower limb the blood from the superficies of the outer parts of the leg and foot passes into the commencement of the main efferent vein, the popliteal vein, at the middle of the limb, that is, in the region of the knee, whilst the blood from the superficial parts of the inner aspect of the lower limb is poured into the femoral vein near the root of the limb in the upper part of Scarpa's triangle.

In addition to the above-mentioned differences in the general arrangement of the veins of the upper and the lower extremities, it must also be noted that in the upper extremity all the blood of the limb, both that from the shoulder-girdle region as well as that from the projecting portion of the limb, is returned to the main efferent venous trunk; but in the lower extremity the greater part of the blood from the region of the pelvic girdle, and a considerable portion from that of the thigh, is returned by the gluteal, obturator, sciatic, and pudic veins to the internal iliac vein, which in the adult is not the main efferent vein of the lower extremity.

The Deep Veins of the Lower Extremity.

All the arteries of the lower limb except the popliteal and femoral trunks are accompanied by two *venæ comites.* They usually lie one on each side of the artery; they are connected with each other by transverse channels which pass in front of or behind the artery, and they are provided with numerous valves.

The **popliteal vein** (v. poplitea, Fig. 575) is formed, at the lower border of the popliteus muscle, by the union of the venæ comites of the anterior and posterior tibial arteries. At its commencement it lies to the inner side of and somewhat

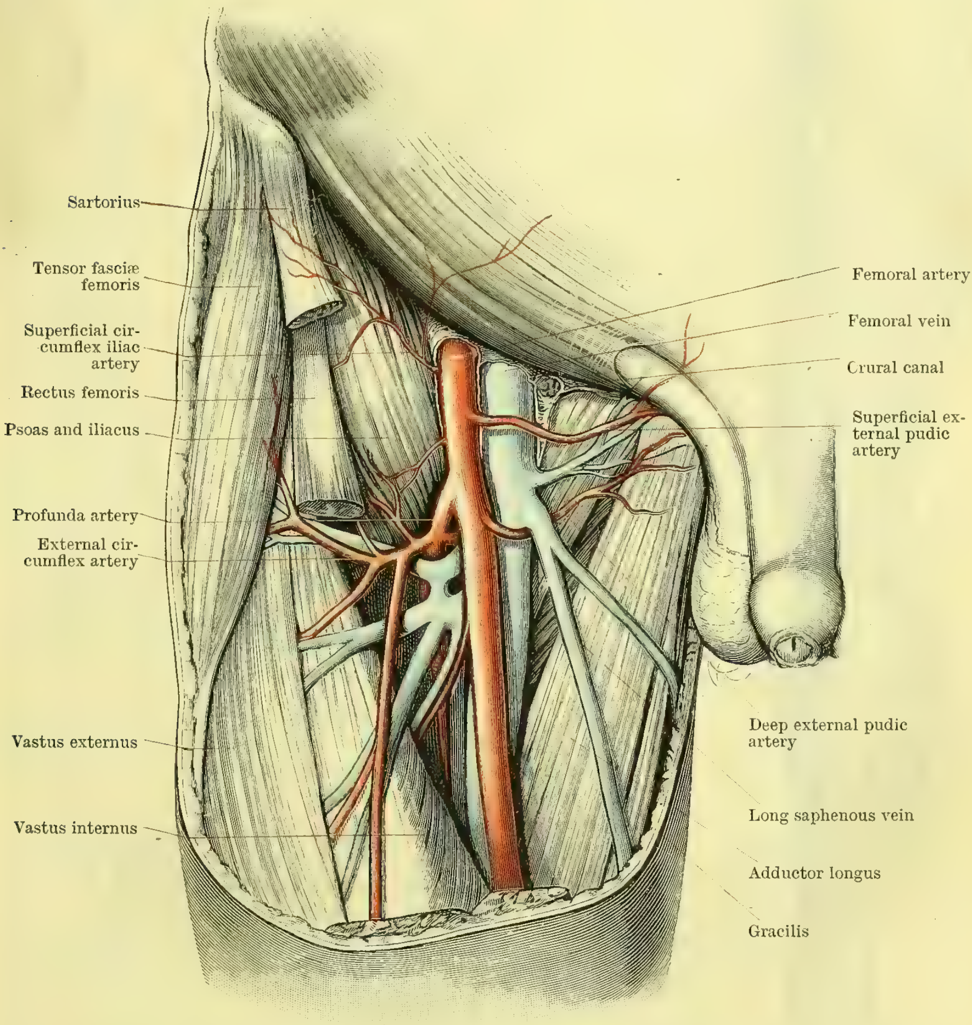


Fig. 588.—The Femoral Vessels in Scarpa's Triangle.

superficial to the popliteal artery, and to the outer side of the internal popliteal nerve. As it ascends through the popliteal space it gradually inclines towards the outer side of the artery, and in the middle of the space it is directly behind the artery, separating the artery from the internal popliteal nerve, which is still more posterior, whilst at the upper end of the space it is to the outer side of the artery, and still between it and the internal popliteal nerve. It then passes through the adductor magnus muscle and becomes the femoral vein.

The popliteal vein, which is provided with two or three bicuspid valves, is closely bound to the artery by a dense fascial sheath. Not uncommonly there are one or more additional satellite veins which anastomose with the popliteal vein, and in these cases the artery is more or less completely surrounded by venous trunks.

Tributaries.—In addition to the venæ comites of the anterior and posterior tibial arteries, it receives tributaries which correspond with the branches of the popliteal artery, and it also receives one of the superficial veins of the leg, viz. the external or short saphenous vein.

Fig. 589.—The Internal or Long Saphenous Vein and its Tributaries.

The **femoral vein** (v. femoralis) is the direct continuation of the popliteal vein. It commences at the junction of the middle and lower thirds of the thigh, at the opening in the adductor magnus muscle. It then ascends through Hunter's canal, and through Scarpa's triangle, and terminates a little to the inner side of the middle of Poupart's ligament by becoming the external iliac vein.

In Hunter's canal it lies behind, and at first to the outer side of, the femoral artery, and upon the adductors longus and magnus which separate it from the profunda vessels. In the lower part of Scarpa's triangle it is behind and to the inner side of the artery, and immediately in front of the profunda vein which separates it from the profunda artery, but in the upper part of Scarpa's triangle it is directly on the inner side of the femoral artery. About one and a-half inches below Poupart's ligament it enters the middle compartment of the femoral sheath, through which it ascends to its termination, lying between the compartment for the femoral artery on the outer side and the crural canal on the inner side.

It usually contains two bicuspid valves, one near its termination and the other just above the entrance of its profunda tributary.

Tributaries.—It receives tributaries (venæ comites) which correspond with the branches of the femoral artery and the larger of the two superficial veins of the lower extremity, viz. the long saphenous vein, which enters the femoral vein where that vessel lies in the middle compartment of the femoral sheath.

The **external iliac vein** (v. iliaca externa, Figs. 569, 572, and 587) is the upward continuation of the femoral vein. It commences on the inner side of the termination of the external iliac artery, immediately behind Poupart's ligament, and ascends along the brim of the pelvis to a point opposite the lumbo-sacral articulation, and immediately behind the internal iliac artery, where it ends by joining the internal iliac vein to form the common iliac vein. It lies at first on the inner side of the external iliac artery, but on a somewhat posterior plane, and then directly behind the artery, whilst just before its termination it crosses the outer side of the internal iliac artery, and separates that vessel from the inner border of the psoas muscle. In its whole

course the vein lies anterior to the obturator nerve. It is usually provided with one bicuspid valve, but sometimes there are two. Its tributaries correspond to the branches of the external iliac artery; thus the deep circumflex iliac (v. circumflex ilium profunda) and deep epigastric (v. epigastrica inferior) veins open into it close to its origin, whilst in addition it frequently receives the pubic vein.

The **pubic vein** forms a communication between the obturator vein and the external iliac vein. It varies in size, and may form the main termination of the obturator vein from which it arises. Commencing in the obturator foramen, it ascends at the side of the pubic branch of the deep epigastric artery, and reaches the external iliac vein.

The Superficial Veins of the Lower Extremity.

The superficial veins of the lower extremity terminate in two trunks, one of which, the **external** or **short saphenous vein**, passes from the foot to the popliteal space; whilst the other, the **internal** or **long saphenous vein**, extends from the foot to the groin.

The superficial veins of the sole of the foot form a fine plexus, immediately beneath the skin, from which anterior and lateral efferents pass. The anterior efferents terminate in a transverse arch which lies in the furrow at the roots of the toes, and the lateral efferents pass round the sides of the foot to the internal or external saphenous veins. The transverse arch also receives small plantar digital veins from the toes, and it gives off interdigital efferent branches to the dorsal venous arch.

The superficial veins on the dorsal aspect of each toe unite together to form two **dorsal digital veins** (v. digitales pedis dorsales) which run along the borders of the dorsal surface. The dorsal digital veins of the adjacent borders of the interdigital clefts unite, at the apices of the clefts, to form four dorsal interdigital veins which terminate in the dorsal venous arch. The dorsal digital vein from the inner side of the great toe ends in the long saphenous vein, and that from the outer side of the little toe terminates in the short saphenous vein.

The **dorsal venous arch** (arcus venosus dorsalis pedis) lies in the subcutaneous tissue, between the skin and the branches of the musculo-cutaneous nerve, opposite the lower parts of the shafts of the metatarsal bones. It ends internally by uniting with the inner dorsal digital vein of the great toe to form the long saphenous vein, and externally by joining the outer dorsal digital vein of the little toe to form the short saphenous vein. The dorsal venous arch receives the dorsal interdigital veins and interdigital efferents from the plantar transverse arch in front, and numerous tributaries from the dorsum of the foot, which anastomose freely together, forming a wide-meshed dorsal venous plexus, open into it behind.

The **internal** or **long saphenous vein** (v. saphena magna) is formed by the union of the inner extremity of the dorsal venous arch with the inner dorsal digital vein of the great toe. It passes upwards in front of the internal malleolus, crosses the inner surface of the lower part of the shaft of the tibia, and ascends immediately behind the internal border of that bone to the knee, where it lies just behind the internal condyle of the femur; continuing upwards, with an inclination forwards and outwards, it gains the upper part of Scarpa's triangle, where it perforates the cribriform fascia and the femoral sheath to reach its termination in the femoral vein. In the foot and leg it is accompanied by the long saphenous nerve, and for a short distance below the knee by the superficial branch of the anastomotic artery. In the thigh, branches of the internal cutaneous nerve lie in close relation with it. It contains from eight to twenty bicuspid valves.

Tributaries.—It communicates freely through the deep fascia with the deep intermuscular veins. In the foot it receives tributaries from the inner part of the sole and from the dorsal venous plexus. As it ascends in the leg it is joined by tributaries from the dorsum of the foot, the inner side and back of the heel, the front of the leg and the back of the calf, and it anastomoses freely with the short saphenous vein. In the thigh it receives numerous tributaries, some of which usually converge to form two **superficial femoral veins.** Of these, one, the *external*, ascends from the outer side of the knee and

terminates in the internal saphenous vein about the lower part of Scarpa's triangle; the other, the *internal*, receives a communication from the external saphenous vein, and ascends from the back of the thigh along its inner side to terminate in the long saphenous vein almost opposite the termination of the external superficial femoral vein. The last tributaries to enter the long saphenous vein are the **superficial circumflex iliac, epigastric,** and **pudic veins.** They accompany the corresponding arteries, and terminate in the long saphenous vein immediately before the latter vessel perforates the cribriform fascia.

The superficial circumflex iliac vein receives blood from the lower and outer part of the abdominal wall and the upper and outer part of the thigh. The superficial epigastric vein drains the lower and inner part of the abdominal wall, and the superficial pudic vein receives blood from the dorsum of the penis and the scrotum in the male, and from the labium majus in the female.

Fig. 590.—The External or Short Saphenous Vein and its Tributaries.

The **external** or **short saphenous vein** (v. saphena parva) is formed by the union of the outer extremity of the dorsal venous arch with the outer dorsal digital vein of the little toe. At first it passes backwards along the outer side of the foot and below the external malleolus, lying on the external annular ligament in company with the external saphenous nerve; then it ascends behind the external malleolus, and along the outer border of the tendo Achillis, still in company with the external saphenous nerve, to the middle of the calf, above which it is continued in the superficial fascia, accompanied by the superficial sural artery, to the lower part of the popliteal space, where it pierces the deep fascia, and terminates in the popliteal vein. It communicates round the inner side of the leg with the internal saphenous vein, and through the deep fascia with the deep veins, and it contains from six to twelve bicuspid valves.

Tributaries.—It receives tributaries from the outer side of the foot, from the outer side and back of the heel, from the back of the leg, and occasionally a descending tributary from the back of the thigh. Just before it pierces the popliteal fascia it gives off a small branch which ascends round the inner side of the thigh and unites with the internal superficial femoral vein. In this way a communication is established between the external and internal saphenous veins; this communication is frequently enlarged, and not uncommonly constitutes the main continuation of the external saphenous vein.

THE PORTAL SYSTEM.

The portal system includes the veins which convey blood from almost the whole of the abdominal and pelvic parts of the alimentary canal, and from the spleen and pancreas, to the liver. The tributaries of origin of these veins agree closely with the terminal branches of the corresponding arteries. They are single vessels, which for some distance accompany the corresponding arteries, and are similarly named. The larger or terminal veins, however, leave their associated arteries; the **inferior mesenteric vein** joins the **splenic vein,** and the latter unites

with the **superior mesenteric vein** to form the **portal vein,** which passes to the liver. These veins, together with their tributaries, constitute the portal system. All the vessels of this system are devoid of valves.

The **portal vein** (vena portæ) is a wide venous channel, about three inches long, which conveys blood from the stomach, from the whole of the intestine, except the terminal portion of the rectum, and from the spleen and pancreas to the liver. Unlike other veins, it ends like an artery by breaking up into branches, which ultimately terminate in capillaries in the substance of the liver; from these portal capillaries the hepatic veins (p. 848), which also receive the blood conveyed

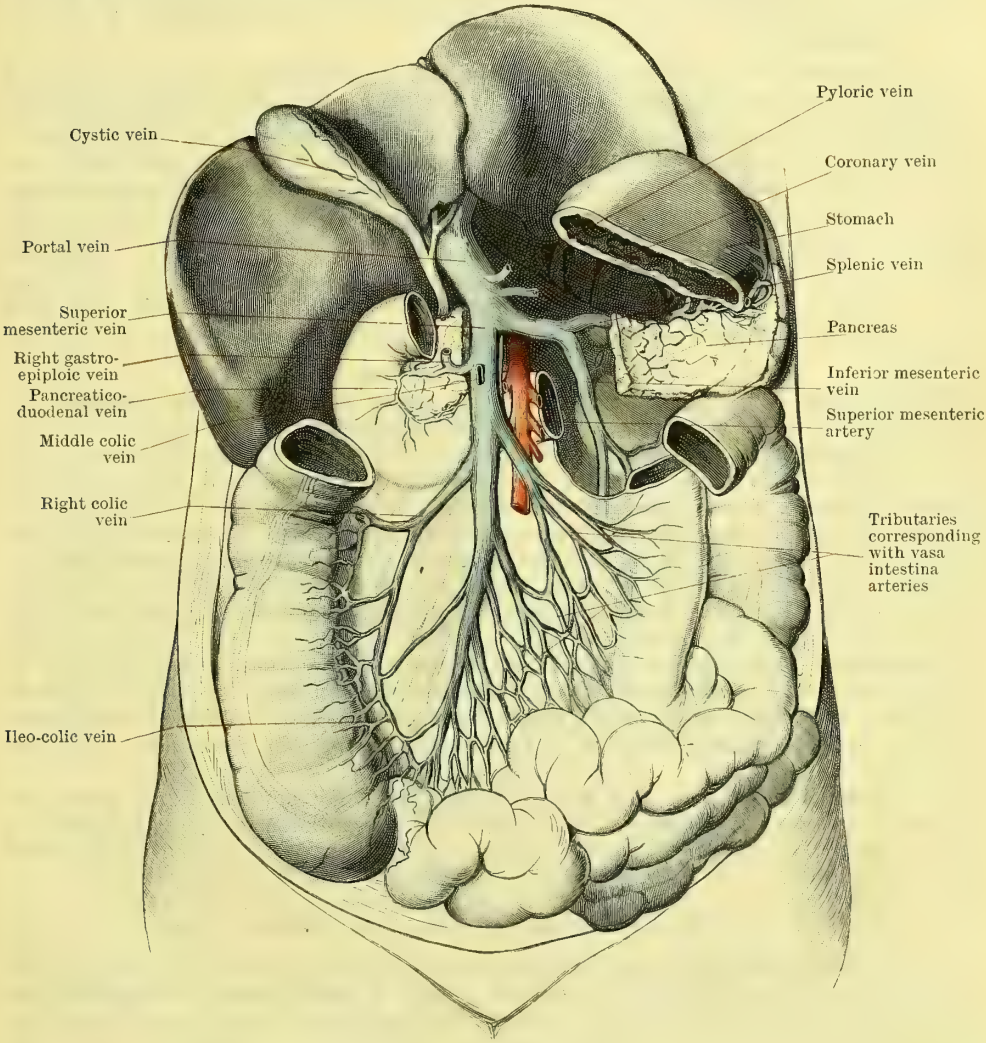


FIG. 591.—THE PORTAL VEIN AND ITS TRIBUTARIES.

to the liver by the hepatic artery, arise; and as these open into the inferior vena cava, the portal blood ultimately reaches the general systemic circulation.

The portal vein commences by the union of the superior mesenteric and the splenic veins behind and to the left of the neck of the pancreas, and either in front of the left border of the inferior vena cava, at the level of the body of the first lumbar vertebra, or in front of the upturned extremity of the lower portion of the head of the pancreas. It ascends in front of the inferior vena cava, and behind the neck of the pancreas and the first part of the duodenum, to the lower border of the foramen of Winslow, where it passes forwards, in the right pancreatico-gastric fold of peritoneum, and enters the lower border of the gastro-hepatic

omentum; continuing its upward course, it lies behind the common bile-duct and hepatic artery, and in front of the foramen of Winslow; it ultimately reaches the right end of the transverse fissure of the liver, where it ends by dividing into a short and wide right and a longer and narrower left branch. Just before its termination it enlarges, forming the sinus of the portal vein.

The **right branch** generally receives the **cystic vein** and then enters the right lobe of the liver, in which it breaks up into numerous branches which terminate in the portal capillaries round the periphery and in the substance of the liver lobules.

The **left branch** runs from right to left along the transverse fissure, giving off branches to the Spigelian and quadrate lobes; it crosses the longitudinal fissure, and ends in a similar manner to the right branch, but in the substance of the left lobe of the liver.

As it crosses the longitudinal fissure, the left branch of the portal vein is joined in front by the **round ligament** of the liver, a fibrous cord which is the remains of the left umbilical vein of the fœtus; and, somewhat to the right of the attachment of the round ligament anteriorly, a fibrous cord springs from it posteriorly and connects it with the upper part of the inferior vena cava; this cord is the remains of the **ductus venosus**, a blood-vessel of the fœtus, through which blood coming from the placenta, by the umbilical vein, passed into the inferior vena cava without going through the liver.

The portal vein is accompanied by numerous lymphatic vessels, and it is surrounded in the gastro-hepatic omentum by filaments of the hepatic plexus of nerves.

Tributaries.—Soon after its formation the portal vein receives the coronary and pyloric veins, and the cystic vein opens into its right branch.

The **coronary vein** (v. coronaria ventriculi) commences in the gastro-hepatic omentum by the union of tributaries from both surfaces of the stomach. It runs to the left between the layers of the gastro-hepatic omentum, and along the lesser curvature of the stomach, with the corresponding artery, to the œsophagus, where it receives œsophageal tributaries. It then turns backwards in the left pancreatico-gastric fold, and reaches the posterior wall of the abdomen, where it again changes its direction to run from left to right, behind the lesser sac of the peritoneum, to the right pancreatico-gastric fold, at the root of which it opens into the portal vein.

The **pyloric vein** (v. pylorica) is a small vessel which is formed by the union of tributaries from the upper parts of both surfaces of the stomach. It runs from left to right along the right portion of the lesser curvature, between the layers of the gastro-hepatic omentum, and terminates in the portal vein, after that vessel has entered the gastro-hepatic omentum.

The **cystic vein** (v. cystica) is formed by the union of tributaries which accompany the branches of the cystic artery on the upper and lower surfaces of the gall-bladder; it ascends along the cystic duct, and as a rule terminates in the right branch of the portal vein.

The Mesenteric and Splenic Veins.

The **superior mesenteric vein** (v. mesenterica superior) commences in the right iliac fossa in connection with the lower part of the ileum. It ascends along the right side of the superior mesenteric artery in the root of the mesentery, forming a curve with the convexity to the left.

As it ascends it passes in front of the right ureter, the lower part of the inferior vena cava, the third part of the duodenum, and the lower part of the head of the pancreas; and, after passing behind the root of the transverse mesocolon, it terminates behind the neck of the pancreas by uniting with the splenic vein to form the portal vein.

Its **tributaries** correspond with the branches of the superior mesenteric artery. It is formed by the union of the ileo-cæcal and appendicular veins. In front and towards the left side the tributaries (vv. intestinales) from between the folds of the mesentery enter it; the right colic and ileo-colic veins enter its right side; the middle colic vein joins it in front at the lower border of the head of the pancreas, and close to its termination it receives the right gastro-epiploic and the pancreatico-duodenal veins.

The **right gastro-epiploic vein** (v. gastroe-piploica dextra) runs from left to right along the lower border of the stomach, and between the two anterior layers of the great omentum. It receives tributaries from both surfaces of the stomach, and near the pylorus turns backwards in

the right pancreatico-gastric fold of peritoneum, passes behind the neck of the pancreas, and ends in the superior mesenteric vein.

The **pancreatico-duodenal** vein receives tributaries (vv. pancreatico-duodenalis) from the head of the pancreas and the adjacent parts of the duodenum ; it ascends along the superior pancreatico-duodenal artery, and terminates in the upper part of the superior mesenteric vein.

The **splenic vein** (v. lienalis) is formed by the union of five or six tributaries which issue from the hilus on the anterior surface of the spleen. It passes backwards and inwards in the lieno-renal ligament to the kidney, then turning to the right it runs behind the upper border of the pancreas and below the splenic artery ; it crosses the front of the abdominal aorta, immediately below the origin of the cœliac axis, and terminates behind the neck of the pancreas, by joining the superior mesenteric vein to form the portal vein.

Tributaries.—It receives the vasa brevia or gastric veins, the left gastro-epiploic vein, the pancreatic veins, and the inferior mesenteric vein. Occasionally the coronary vein terminates in it.

The **vasa brevia** or **gastric veins** (vv. gastricæ breves) are a series of small venous channels which gather blood from the region of the left portion of the great curvature of the stomach ; they pass backwards towards the spleen in the gastro-splenic omentum, and terminate either in the trunk of the splenic vein or in one of its main tributaries.

The **left gastro-epiploic vein** runs from right to left along the lower border of the stomach between the layers of the great omentum. At the left extremity of the stomach it enters the gastro-splenic omentum, through which it passes towards the hilus of the spleen, and it terminates in the commencement of the splenic vein. It receives tributaries from both surfaces of the stomach.

The **pancreatic veins** issue from the substance of the pancreas, and terminate directly in the splenic vein.

The **inferior mesenteric vein** (v. mesenterica inferior) commences, as the superior hæmorrhoidal vein, in the venous plexus which lies between the muscular and mucous coats of the rectum. The **superior hæmorrhoidal vein** (v. hæmorrhoidalis superior) drains the greater part of the blood from the hæmorrhoidal plexus, through which it communicates with the middle and inferior hæmorrhoidal veins. It ascends in company with the superior hæmorrhoidal artery, and between the layers of the meso-rectum, to the brim of the pelvis, where it passes in front of the left common iliac artery and becomes the inferior mesenteric vein.

The inferior mesenteric vein runs upwards on the left of the aorta, behind the peritoneum, and in front of the left psoas muscle and the left spermatic artery. Near its termination it crosses in front of the left renal vein, and, passing behind the body of the pancreas, ends in the splenic vein. Occasionally it terminates in the angle of union of the superior mesenteric and splenic veins.

Tributaries.—In addition to the superior hæmorrhoidal vein, of which it is the direct continuation, the inferior mesenteric vein receives **sigmoid tributaries** (vv. sigmoideæ) from the iliac and pelvic colon, and the **left colic vein** from the descending colon and splenic flexure.

THE LYMPH VASCULAR SYSTEM.

The vessels of the lymph vascular system (vasa lymphatica) contain a colourless fluid, rich in white corpuscles, called lymph. In many respects they resemble blood-vessels, especially the veins ; but unlike veins they communicate with intercellular spaces and with serous sacs, and their continuity is interrupted by interposed nodular aggregations of lymph tissue which are known as **lymph glands** (lymphoglandulæ).

Lymph is collected in intercellular spaces from which lymph capillaries arise ; the latter terminate in lymphatic vessels, which unite together, forming larger vessels ; and ultimately two terminal trunks—viz. the **thoracic duct** and the **right lymphatic duct**—open into the venous system, at the commencement respectively of the left and right innominate veins.

There are no outgoing vessels, but it is customary to speak of afferent (vasa afferentia) and efferent (vasa efferentia) lymphatics with reference to vessels which enter or leave the interposed glands.

Lymph vessels, and the spaces in which they commence, merely collect and convey lymph. The lymphatic glands act, in part at least, as filters, and possibly also some of the white corpuscles are formed in them.

The greater part, if not the whole, of the lymph of the body passes through one or more of the lymph glands before it reaches the blood vascular system.

Lymphatic spaces.—Lymph spaces are simply intervals or clefts in connective

tissue. The larger spaces are lined by a layer of flattened endothelial cells, with sinuous outlines, similar to the cells of the lymphatic capillaries; but the smaller spaces have no endothelial lining, and they are limited only by the cells of the tissue in which they lie. The precise nature of the communications between lymphatic spaces and lymph capillaries has not been definitely ascertained; but undoubtedly lymph passes from the spaces into the capillaries, and probably it does so because the spaces and vessels are directly continuous.

As alternative explanations, it may be suggested either that the passage is due to the existence of stomata in the walls which separate spaces from the capillaries, or that it may be due to transudation through intervening tissues.

Lymph capillaries.—Lymph capillaries are not only much larger and more irregular than blood capillaries, but they are also larger than the lymphatic vessels into which they open. They are lined by a single layer of endothelial cells which possess very sinuous outlines; apparently they are in direct structural continuity with lymph spaces, and they anastomose freely together, forming plexiform labyrinths.

Lymphatic vessels.—The smallest lymphatic vessels are much narrower in calibre than the lymph capillaries with which they are continuous. Their walls consist of an internal lining of endothelial cells of fusiform shape and regular outline, and an outer layer of fine connective tissue. They are provided with numerous valves, and when distended have a beaded appearance.

The larger lymph vessels possess three coats — (1) An internal coat (tunica interna), formed by a layer of endothelial cells, of fusiform shape, and of regular, but sinuous, outline. (2) A middle coat (tunica media) of unstriped muscle fibres, arranged for the most part circularly, but some of which run obliquely or longitudinally. The interspaces between the muscle fibres are filled with a fine connective tissue. (3) An outer coat (tunica externa) of mixed white fibrous and elastic tissue, which is not sharply separated from the middle coat on the inner side or from the surrounding tissues on the outer side. It may also contain a few unstriped muscle fibres. In the largest vessels the two outer coats consist principally of muscle; they are, therefore, very friable.

All the large vessels are provided with numerous bicuspid valves, which are formed by folds of the inner coat; and as the lumina of the vessels are enlarged just above the attachments of the valves, the vessels assume a characteristic beaded appearance when they are distended.

Lymphatic vessels anastomose freely together, and the majority form communicating channels between different groups of lymphatic glands, leaving the more distal glands as *efferent vessels* and entering the more proximal glands as *afferent vessels.* Some of the lymphatic vessels, however, are afferent only; they simply carry lymph from the periphery to the nearest glands; whilst others, which carry lymph from the last set of glands to the terminal trunks, are efferent only.

The lymphatic vessels, unlike the veins which they usually accompany, do not increase greatly in calibre as they converge towards their terminations; they often branch, and they frequently anastomose together. In certain places, particularly the central nervous system and the spleen, lymph capillaries or even lymphatic vessels completely ensheath the smaller blood-vessels, forming perivascular lymphatic spaces.

Lymphatic glands. — Lymphatic glands are globular, ovoid, flattened, or irregular bodies, and each gland presents a localised depressed area which is known as the hilus. They vary considerably in size, some being no larger than a pin's-head, whilst others are as large as a bean. In colour they are usually grayish pink, but the tint varies with the position, vascularity, and state of activity of the gland. The glands of the lung are generally blackened by the deposition of carbonaceous material in their substance, and those of the liver and spleen have frequently a brownish hue. The glands of the mesentery are creamy or white whilst the chyle is rapidly passing through them, but when the absorption of food-material from the intestine ceases they become a rosy pink.

Structure of Lymphatic Glands.—Lymphatic glands consist of (1) a skeleton or framework, (2) lymph sinuses, and (3) lymph follicles and cords.

(1) The **skeleton** or framework consists of a **capsule** and of primary, secondary, and tertiary **trabeculæ.**

The *capsule* is formed of white fibrous tissue interspersed with elastic fibres, and in some cases with unstriped muscular fibres.

The *primary trabeculæ* spring from the deep surface of the capsule and radiate towards the hilus, where they anastomose together and become again continuous with the capsule; they divide the interior of the gland into lobes. Where they spring from the capsule they are flattened, but as they approach the centre of the gland they become rounded; their structure is the same as that of the capsule, and from their surfaces the secondary trabeculæ are given off. The *secondary trabeculæ*, springing from the surfaces of the primary trabeculæ, cross the lymph sinuses and enter the lymph cords and follicles, where they terminate by dividing into tertiary trabeculæ. As they cross the lymph sinuses they anastomose freely together, forming a fine mesh-work through which the lymph passes in its course from the afferent to the efferent vessels. The secondary trabeculæ consist of fine strands of fibrous tissue devoid of nuclei, and their surfaces are covered with endothelial cells. The *tertiary trabeculæ* are finer and more delicate than the secondary trabeculæ, from the terminations of which they spring, but they have a similar structure. They anastomose together, forming a fine network in the lymph cords and follicles, and the spaces of the network are filled with lymph corpuscles.

(2) The **lymph sinuses** lie beneath the capsule and around the primary trabeculæ which form their boundaries on one side, whilst on the other they are limited by the lymph cords and follicles. They are traversed by the secondary trabeculæ, and their channels are thus converted into a kind of sponge-work through which the lymph stream flows. In the peripheral or cortical parts (substantia corticalis) of the glands they form more or less cylindrical channels, but towards the central or medullary parts (substantia medullaris) and near the hilus they become moniliform. Afferent vessels (vasa afferentia) enter the sinuses which lie immediately beneath the capsule at various points, whilst the efferent vessels (vasa efferentia) emerge close together at the hilus.

(3) The **lymph follicles and cords** are interposed between the lymph sinuses. They consist of dense masses of lymphoid cells embedded in a stroma formed by the tertiary trabeculæ. The follicles and cords are quite similar in structure, but the follicles are large masses which intervene between the sinuses in the cortex of the gland, and the cords are rounded and irregular strands which lie between the moniliform sinuses of the medullary portion.

It is generally believed that the lymph corpuscles in the follicles and cords are white blood corpuscles undergoing proliferation. If this belief is well founded, lymph glands must be looked upon as one of the sources from which white corpuscles are derived.

The **lymph glands** are embedded in the connective tissues, some lying superficially in the subcutaneous tissues, but the majority more deeply and usually at the sides of the great blood-vessels. As a rule they are arranged in groups of from two to fifteen, but a few of those which lie in the subcutaneous tissues are solitary.

They form centres to which afferent lymphatic vessels converge, and from which efferent vessels pass onwards to the larger lymph channels.

The student should therefore acquaint himself with the various groups of glands, with their afferents and efferents, and with the exact position and relations of the large lymphatic trunks; he will then be in a position to understand the course which minute organisms or particles, which have gained access to the lymph spaces, may take as they are carried in the lymph stream, and he will realise that such structures may either be entangled in the glands through which the lymph passes, or, having escaped all obstructions, that they will finally enter the veins at the root of the neck. At the same time, if he bears in mind the existence of the numerous anastomoses between the lymphatic vessels, he will have no difficulty in appreciating that variations from any regular course may not infrequently occur, and his clinical experience at a later period will show that such variations are by no means uncommon.

THE TERMINAL LYMPH VESSELS.

The terminal lymph vessels are the **thoracic duct** and the **right lymphatic duct.**

Thoracic Duct.—The thoracic duct (ductus thoracicus) is the larger and the longer of the two terminal lymph vessels. It commences in the umbilical region of the abdomen as an elongated ovoid dilation—the **receptaculum chyli** (cisterna chyli)—which measures 6 to 8 mm. ($\frac{1}{6}$ to $\frac{1}{3}$ in.) in its broadest diameter, and from 5 to 7·5 cm. (2 to 3 in.) in length. The receptaculum chyli lies between the aorta and the lower part of the vena azygos major, under cover of the right crus of the diaphragm, and opposite the first and second lumbar vertebræ. Passing

upwards from the receptaculum, the thoracic duct traverses the aortic opening of the diaphragm and enters the posterior mediastinum, through which it ascends, lying in front of the vertebral column and to the right of the middle line, to the level of the fifth dorsal vertebra; it then crosses somewhat abruptly from the right to the left of the median plane, and ascends through the superior mediastinum to

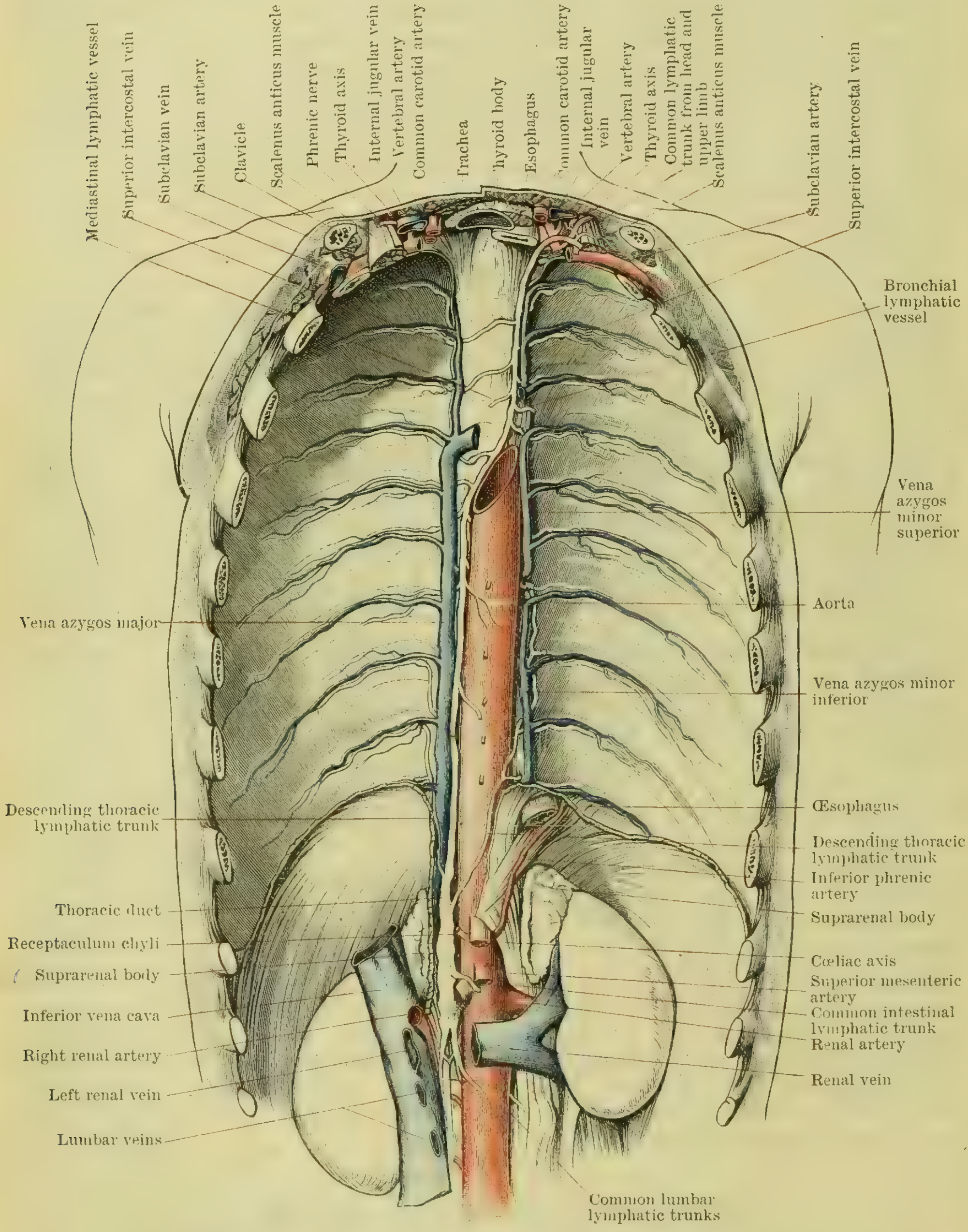


FIG. 592.—THE THORACIC DUCT AND ITS TRIBUTARIES.

the root of the neck, where it turns outwards, between the vertebral and common carotid arteries, to terminate at the inner border of the scalenus anticus by joining the commencement of the left innominate vein.

Length and diameter.—The total length of the duct averages about 18 inches (45 cm.). It is dilated both at its origin and termination. As a rule it is narrowest opposite the fifth dorsal vertebra, but its calibre is very variable, and

sometimes the thoracic portion is broken up into a series of anastomosing channels. The widest portion of the tube is usually the receptaculum, but occasionally this dilatation is entirely absent. The duct is provided with several valves, formed by semilunar folds of the inner coat, arranged in pairs, and the most perfect of these is situated at the orifice of communication with the innominate vein.

Relations.—In the abdomen the receptaculum chyli lies in front of the upper two lumbar vertebræ, between the aorta on the left and the vena azygos major and the right crus of the diaphragm on the right. In the posterior mediastinum it is separated from the vertebral column and the anterior common ligament, by the right aortic intercostal arteries and the transverse parts of the small azygos veins; it is covered in front in the lower part of its extent by the right pleural sac, and in the upper part by the œsophagus; to its right is the vena azygos major, and to its left the descending aorta. In the superior mediastinum it passes forwards from the vertebral column, and it is separated from the left longus colli muscle by a mass of fatty tissue; in front of it, in the lower part of this region, is the terminal part of the arch of the aorta, and at a higher level the left subclavian artery. As the duct enters the root of the neck it passes behind the left common carotid artery, whilst to its right and somewhat in front is the œsophagus, and to its left the left pleura.

At the root of the neck it arches outwards above the apex of the pleural sac and the first part of the left subclavian artery. It passes in front of the vertebral artery and vein, the root of the inferior thyroid artery, the inner border of the scalenus anticus and the phrenic nerve, and behind the left carotid sheath and its contents.

Tributaries.—The receptaculum chyli generally receives five tributaries. (1) The **common intestinal lymphatic trunk** (truncus intestinalis), which conveys lymph from the lower and anterior part of the liver, the stomach, the small intestine, the spleen, and the pancreas. (2) Two **common lumbar lymphatic trunks** (trunci lumbales), one on each side; they carry lymph from the lower extremities, from the deep portions of the abdominal and pelvic walls, the large intestine and the pelvic viscera, and from the kidneys and suprarenal capsules; and (3) two **descending lymphatic trunks**, one on each side, each of which is formed by the efferent vessels from the corresponding lower intercostal glands; these descend to the receptaculum through the aortic opening of the diaphragm.

In its course through the posterior mediastinum the thoracic duct receives efferents from some of the lower intercostal glands on the left side, a few from the upper and back part of the liver, and others from the posterior mediastinal glands.

In the superior mediastinum the vessels which open into it are derived from the upper left intercostal glands, the left half of the heart and pericardium, and the left lung and pleura. It also receives some of the efferents of the superior mediastinal and sternal glands.

At the root of the neck, just before its termination, it receives the efferents from the glands of the left upper extremity, which frequently unite to form a common trunk (truncus subclavius), and the left common jugular lymphatic (truncus jugularis), which conveys the lymph from the left side of the head and neck.

Right Lymphatic Duct.—The right lymphatic duct (ductus lymphaticus dexter, Fig. 596) is a short trunk, from half to three-quarters of an inch (12 to 17 mm.) in length, which lies at the right side of the root of the neck along the inner border of the scalenus anticus. It is formed by the confluence of the right common jugular lymphatic vessel and the efferent vessels from the glands of the right upper extremity; it also receives efferents from the intercostal glands of the upper intercostal spaces on the right side and from the visceral thoracic glands on the right side. It thus receives lymph from the right side of the head and neck, the right upper limb and the right side of the trunk, including the upper part of the thoracic wall, the right lung and pleura, the right half of the heart and pericardium, the right side of the diaphragm, and the upper surface of the liver.

THE LYMPHATIC VESSELS AND GLANDS OF THE HEAD AND NECK.

The **lymphatic vessels of the head and neck** form two groups, (1) the intracranial and (2) the extracranial.

(1) The **intracranial lymphatics** are (*a*) the cerebral and (*b*) the meningeal.

(*a*) The **cerebral lymphatic vessels** commence in the substance of the brain as perivascular spaces round the branches of the cerebral arteries; they accompany the cerebral branches of the internal carotid and the vertebral arteries, and, leaving the skull with the main arterial trunks and the internal jugular vein, terminate in the upper deep cervical glands.

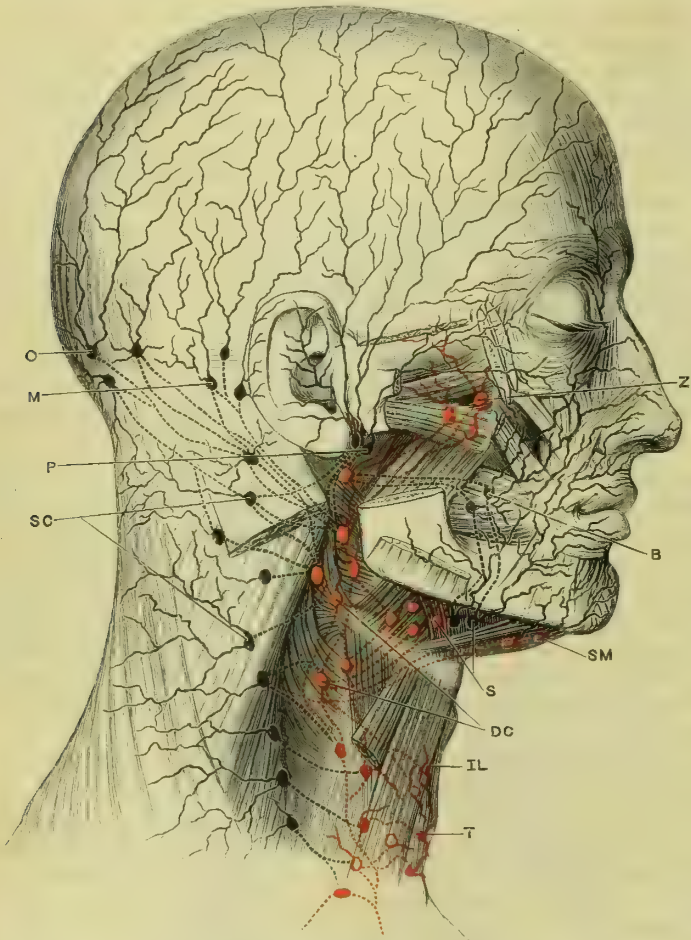


FIG. 593.—LYMPHATIC VESSELS AND GLANDS OF THE HEAD AND NECK. The deep lymphatics are coloured red, the superficial black. In each set the afferent vessels are shown in continuous lines; the efferent and interglandular vessels are represented by dotted lines.

B.	Buccal glands.	P.	Superficial parotid glands.
D.C.	Deep cervical glands.	S.	Submaxillary glands.
I.L.	Infra-laryngeal glands.	S.C.	Superficial cervical glands.
M.	Mastoid glands.	S.M.	Submental glands.
O.	Occipital glands.	T.	Tracheal glands.
		Z.	Zygomatic glands.

(*b*) The **meningeal lymphatic vessels** commence in the substance of the dura mater; they accompany the meningeal blood-vessels, and they terminate in the internal maxillary glands and in the upper deep cervical glands.

(2) The **extracranial lymphatics** are either (*a*) superficial or (*b*) deep, and the two sets anastomose freely together.

(*a*) The **superficial lymphatic vessels** commence in the subcutaneous tissues and in the superficial muscles of the face and scalp.

(*b*) The **deep lymphatic vessels** originate in the walls of the nose and mouth, in the tongue, in the walls of the pharynx, the œsophagus, the larynx and trachea, in the contents of the orbital and other extracranial fossæ, and in the muscles, bones, and ligaments of the neck.

All the extracranial lymphatic vessels, both superficial and deep, are afferents to some of the glands of the head or neck, and their general distribution and terminations are mentioned in connexion with the glands with which they are associated.

The **lymphatic glands of the head** include the following:—

The **occipital glands** (lymphoglandulæ occipitales), two or three in number, are embedded in the superficial fascia over the upper part of the trapezius muscle. They receive afferent vessels from the occipital region of the scalp and from the superficial parts of the upper and back portion of the neck, and their efferents terminate in the superficial cervical glands.

The **mastoid glands** (lymphoglandulæ auriculares posteriores) lie in the superficial fascia on the upper part of the sterno-mastoid muscle and on the mastoid

portion of the temporal bone. They receive afferent vessels from the posterior part of the parietal region of the scalp, and from the inner surface of the pinna; their efferents join the superficial cervical glands.

The **zygomatic** or **internal maxillary glands** (lymphoglandulæ faciales profundæ) are very variable both in number and size; they lie with the internal maxillary artery on the posterior part of the buccinator muscle, and on the anterior part of the wall of the pharynx. Their afferent vessels are derived from the orbit, the temporal fossa, the zygomatic fossa, the palate, the nose, and the cerebral meninges. Their efferent vessels open into the upper deep cervical glands.

The **parotid lymphatic glands** (lymphoglandulæ auriculares anteriores), which are embedded in the substance of the parotid gland, some superficially and others deeply. The *superficial* receive afferents from the frontal and the temporal regions of the scalp, from the eyebrow, the upper and lower eyelids, the upper part of the cheek, the root of the nose, and the outer surface of the pinna. Their efferents pass to the superficial and the upper deep cervical glands. The *deep parotid lymphatic glands* (lympho-glandulæ parotideæ) lie along the course of the upper part of the external carotid artery. They receive afferents from the external meatus, the soft palate, the posterior part of the nose, and the deeper portions of the cheek. Their efferents open into the upper deep cervical glands.

The **buccal lymphatic glands** are few in number and small in size; they lie on the outer surface of the anterior part of the buccinator muscle. Their afferents are derived from the cheek and the side of the face, and their efferents join the deep parotid and submaxillary glands.

The **lingual glands** (lymphoglandulæ linguales) lie between the genio-hyo-glossi muscles and, on the outer surfaces of the hyo-glossus and genio-hyo-glossus muscles, under cover of the mylo-hyoid; they receive afferent vessels from the floor of the mouth and the anterior part of the tongue. Their efferents terminate in the upper deep cervical glands.

The **lymphatic glands of the neck** include:—

The **superficial cervical lymphatic glands** (lymphoglandulæ cervicales superficiales). These lie on or are embedded in the deep fascia along the course of the external jugular vein, superficial to the sterno-mastoid and along its posterior border. They receive afferent vessels from the superficial tissues of the neck, the occipital, the mastoid, the superficial parotid, and the submaxillary lymphatic glands. Their efferent vessels terminate in the upper and the lower deep cervical glands.

The **submaxillary lymphatic glands** (lymphoglandulæ submaxillares) are in the submaxillary triangle and in relation with the superficial and deep surfaces of the submaxillary gland. Those which are more superficially situated receive afferent vessels from the superficial part of the nose and from the front and lower part of the face, including the upper lip and the outer part of the lower lip, whilst the afferents of the more deeply situated glands are derived from the floor of the mouth, the anterior part of the tongue, and from the sublingual and submaxillary salivary glands. The efferent vessels open partly into the superficial and partly into the upper deep cervical glands.

The **supra-hyoid glands**, usually two or three in number, lie beneath the chin on the surface of the mylo-hyoid muscle and between the anterior bellies of the digastric muscles. They receive afferent vessels from the lower lip and the chin, and their efferents terminate in the superficial, and in the upper deep cervical glands.

The **post-pharyngeal glands** lie behind the upper part of the pharynx in front of the upper two cervical vertebræ. They receive afferents from the pharynx, the prevertebral muscles and fascia, and the posterior part of the nose. Their efferents open into the upper deep cervical glands.

The **pre-laryngeal glands** are very variable, but occasionally one or two small glands are found in front of the lower part of the larynx, between the crico-thyroid muscles. They receive afferent vessels from the lower part of the larynx, the upper part of the trachea, and the thyroid body. Their efferents terminate in the upper deep cervical glands.

The **pre-tracheal glands** are usually of small size. They lie on the anterior

surface of the trachea, receiving afferents from the trachea and the lower part of the thyroid body, and giving efferents to the lower deep cervical glands.

The **deep cervical glands** lie along the course of the internal jugular vein, and at the root of the neck extend outwards along the subclavian vein. They form two groups, an upper and a lower. (*a*) The *upper deep cervical glands* (lymphoglandulæ cervicales profundæ superiores) extend from the base of the skull to the bifurcation of the common carotid artery. They receive afferents from the interior of the cranium, the posterior part of the nose, the walls of the pharynx, the tonsil, the upper part of the larynx, the thyroid body, the posterior and deep parts of the tongue, and from all the glands of the head and neck except the occipital, mastoid, superficial parotid, pre-tracheal, and the lower deep cervical glands. Their efferents terminate in the lower deep cervical glands. (*b*) The *lower deep cervical glands* (lymphoglandulæ cervicales profundæ inferiores) lie along the lower part of the internal jugular vein, and they extend outwards into the lower part of the posterior triangle. Their afferents are derived from the upper deep cervical glands, the superficial cervical glands, the pre-tracheal glands, the œsophagus, the trachea, the lower part of the pre-vertebral region, and the infra-clavicular glands. Their efferents usually unite to form a common jugular lymphatic trunk which opens on the right side into the right lymphatic duct, and on the left into the thoracic duct.

LYMPHATIC GLANDS AND VESSELS OF THE UPPER EXTREMITY.

The **lymphatic glands of the upper extremity** are divisible into (1) superficial and (2) deep sets.

(1) The **superficial glands** lie in

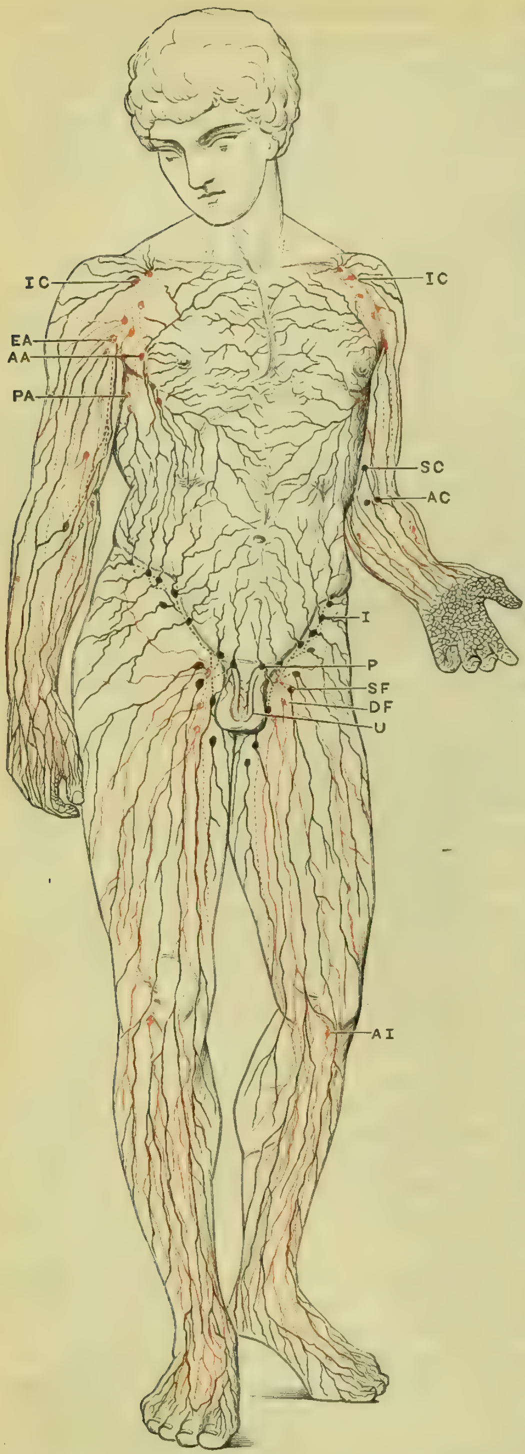


FIG. 594.—SUPERFICIAL LYMPHATIC VESSELS OF THE TRUNK, AND THE LYMPHATIC GLANDS AND VESSELS—SUPERFICIAL AND DEEP—OF THE LIMBS (diagrammatic). All superficial lymphatics are printed black; the deep lymphatics throughout are coloured red. Afferent vessels are represented by continuous lines; efferent and interglandular vessels by dotted lines.

A.A.	Anterior axillary glands.	E.A	External axillary glands.	P.A.	Posterior axillary glands.
A.C.	Ante-cubital glands.	I.	Inguinal glands.	S.C.	Supra-trochlear glands.
A.I.	Anterior tibial glands.	I.C.	Infra-clavicular glands.	S.F.	Superficial femoral glands.
D.F.	Deep femoral glands.	P.	Pubic glands.	U.	Urethral lymphatics.

the subcutaneous tissue, and form two groups, a lower and an upper. The *lower* or *ante-cubital group* is frequently absent; when present it includes two or three glands which lie in front of the elbow; they receive afferent vessels from the front of the forearm and from the median part of the palm, and they give off efferent vessels which pass upwards and inwards along the antero-internal aspect of the arm. At varying levels these efferents pierce the deep fascia and terminate in the external axillary glands. The *upper* or *supra-trochlear group* lies a short distance above the internal condyle; as a rule it includes two glands only, but the number may be increased to four; they lie close to the commencement of the basilic vein, and their afferent vessels are derived from the inner two or three digits, the inner side of the forearm, and the inner side of the palm. Their efferents pass upwards along the basilic vein, which they accompany through the opening in the deep fascia; they then join the deep lymphatics, which are ascending along the brachial artery, and accompany them to the external axillary glands.

(2) The **deep glands** lie along the vessels in the axilla and, just below the clavicle, in the groove between the pectoralis major and the deltoid muscles. They are accordingly divisible into (*a*) the axillary and (*b*) the infra-clavicular glands.

One or two small glands are occasionally found with the arteries of the forearm and a few with the brachial artery; they receive deep afferent lymphatics from the adjacent muscles, ligaments, and the bones, and they give off efferent vessels which terminate in the external axillary glands.

(*a*) The **axillary glands** are arranged in three groups—external, anterior, and posterior.

(i.) The **external group** (lymphoglandulæ axillares) consists of from six or more glands which form a chain along the antero-internal aspect of the axillary vessels, extending from the lower border of the pectoralis major to the outer border of the first rib. They receive afferent vessels, both superficial and deep, from the whole of the upper extremity; many of these pass directly to the glands from the tissues, the remainder include the efferents of the superficial and deep glands of the forearm and arm, the efferents of the infra-clavicular glands, and some of the efferents of the anterior and posterior axillary glands. The efferents of the external axillary glands pass along the subclavian vein, occasionally forming a common trunk, and terminate on the right side in the right lymphatic duct, and on the left side in the thoracic duct.

(ii.) The **anterior axillary** or **pectoral glands** (lymphoglandulæ pectorales), four or five in number, lie at the anterior part of the axilla, in the angle between the pectoral muscles and the serratus magnus. They receive afferent vessels from the superficial parts of the anterior and lateral walls of the body above the umbilicus, and from the outer two-thirds of the mammary gland. Some of their efferents pass to the external axillary glands, but the majority accompany the efferent vessels of the latter glands to their termination.

(iii.) The **posterior** or **subscapular set** of axillary glands (lymphoglandulæ subscapulares), four or five in number, lie along the sides of the subscapular artery on the posterior wall of the axilla. Their afferents are the superficial lymphatics of the lateral and posterior parts of the body-wall, above the umbilicus and the superficial lymphatics of the lower and back part of the neck. Their efferents either join the external axillary glands, or they pass to the root of the neck, where they anastomose with the lower cervical lymphatics, and end either in the right lymphatic or the thoracic duct, according to the side on which they are situated.

(*b*) The **infra-clavicular glands** lie deeply in the groove between the pectoralis major and the deltoid muscles, directly below the clavicle. They receive afferents from the outer side of the arm and the shoulder, which accompany the cephalic vein, and their efferents pass to the external axillary glands or to the lower deep glands of the neck.

The **lymphatic vessels of the upper extremity** are, like the glands, arranged in two sets, (1) the superficial and (2) the deep.

The **superficial lymphatic vessels** commence in cutaneous plexuses which are finest and most dense on the palmar aspects of the fingers and hand. The efferents

from the palmar digital plexuses in each digit converge to four trunks, which lie two on each side in the subcutaneous tissue on the lateral margins of the dorsal aspects of the digits. They accompany the dorsal digital veins, and, at the roots of the digits, they pass to the dorsum of the hand, where they anastomose together. The plexus in the palm of the hand is extremely fine, and efferents pass from it not only upwards, but also downwards and laterally. The upper efferents, three or four in number, accompany the median vein, and terminate either in the superficial glands at the bend of the elbow or in the supra-trochlear glands. The lower efferents pass to the interdigital spaces, and turn backwards to the dorsum to join the digital trunks. The lateral efferents turn round the borders of the hand, those on the inner side join the efferents from the little finger, and those on the outer side the efferents from the thumb. Occasionally some of the efferents which pass towards the outer side fuse to form a fairly large trunk, the so-called

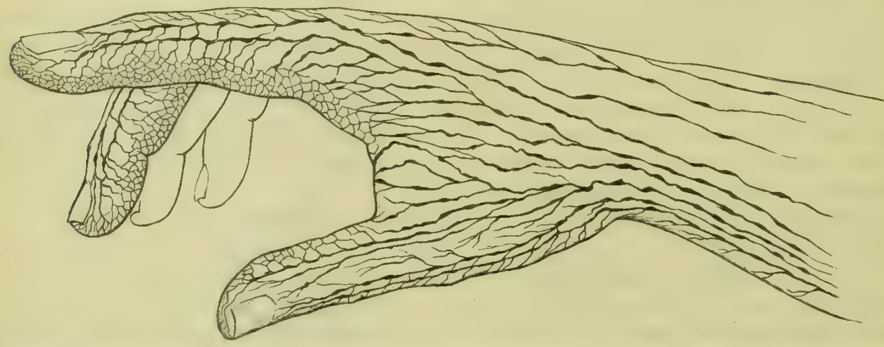


FIG. 595.—SUPERFICIAL LYMPHATICS OF THE DIGITS AND OF THE DORSAL ASPECT OF THE HAND.

central lymphatic which turns round the outer side of the second metacarpal bone and unites with the lymphatic vessels of the thumb and index-finger.

The superficial lymphatic vessels of the forearm, including those which ascend from the dorsum and the palm of the hand, are grouped, for the main part, along the radial, median, and ulnar veins, the lateral vessels being joined at intervals by tributaries from the dorsum of the limb.

The lymphatic trunks which accompany the ulnar veins terminate in the supra-trochlear glands, and those which accompany the median vein in the glands at the bend of the elbow, the ante-cubital glands, or, if these are not present, in the supra-trochlear glands.

The efferent vessels of the ante-cubital and supra-trochlear glands have already been described (p. 867).

A few of the lymphatics of the outer side of the forearm and some of those of the upper arm accompany the cephalic vein and terminate in the infra-clavicular glands.

All the remaining superficial vessels of the upper arm and forearm pass towards the axilla. They pierce the deep fascia, and terminate in the external set of axillary glands.

The **deep lymphatics of the upper extremity** commence in the bones, periosteum, ligaments, muscles, and intermuscular connective tissue; they accompany the main vessels, and some of them terminate in the deep glands of the forearm and arm, but the majority ascend to the external set of axillary glands.

THE LYMPHATIC GLANDS AND VESSELS OF THE LOWER EXTREMITY.

Lymphatic Glands of the Lower Extremity.—Like those of the upper extremity, these are arranged in two sets, (1) superficial and (2) deep.

(1) **Superficial Glands.**—The superficial glands all lie in the region of the groin, and form three groups—the superior, the inferior, and the internal.

(*a*) The **superior** or **inguinal group** includes from four to seven flattened ovoid

glands which lie parallel with and just below Poupart's ligament. They receive afferent vessels from the back and outer part of the thigh and the buttock, and the superficial lymphatics from the body wall below the level of the umbilicus, except those from the lower and anterior part which pass to the internal group of glands. Their efferents pass through the deep fascia, and terminate either in the deep femoral or the external iliac glands.

(*b*) The **inferior** or **femoral group** is formed by from three to six oval glands which are disposed vertically along the upper part of the internal or long saphenous vein. They receive all the superficial lymphatics of the foot and leg, except a few which accompany the external saphenous vein to the popliteal glands; all the superficial lymphatics of the thigh, except those from the upper and outer part, which terminate in the superior set of glands, and a few from the upper and inner part which terminate in the inner group of glands. The efferent vessels of the femoral group pass through the saphenous opening, and terminate either in the deep femoral glands or in the external iliac glands.

(*c*) The **internal** or **pubic group** includes two, three, or four rounded glands which lie internal to the saphenous opening and close to the spine of the pubis. They receive afferent vessels from the lower and middle portion of the abdominal wall, from the upper and inner part of the thigh, from the external genitals, including the lymphatics of the membranous and spongy portions of the urethra in the male, or the lower third of the vagina in the female, and from the perineum, including the lymphatics of the lowest part of the rectum and of the anus, in both sexes. The vessels from the lower third of the vagina and the corresponding part of the rectum communicate not only with the inguinal glands but also with the internal iliac glands. The efferent vessels of the pubic glands communicate with the efferents of the superior and inferior groups, and, after passing through the saphenous opening, they terminate either in the deep femoral or the external iliac glands.

(2) **Deep Glands.**—The deep lymphatic glands of the lower extremity are found on the upper part of the interosseous membrane of the leg, in the popliteal space, and in Scarpa's triangle.

The **anterior tibial gland** (lymphoglandula tibialis anterior) is situated near the anterior tibial artery on the upper part of the front of the interosseous membrane. It receives afferent vessels from the deep parts of the sole and the dorsum of the foot, and from the deep parts of the front of the leg. It gives off two efferent vessels which pass backwards along the anterior tibial artery and terminate in the popliteal glands.

The **popliteal glands** (lymphoglandulæ popliteæ) are four or five in number; they lie in the popliteal space, generally round the popliteal artery, but occasionally there is one immediately beneath the deep fascia near the entrance of the external saphenous vein. They receive afferent vessels from the sole of the foot and the back of the leg, and from the anterior tibial gland; they also receive the superficial lymphatics which accompany the external saphenous vein. The efferent vessels join the deep femoral glands.

The **deep femoral glands,** three or four in number, lie on the inner side of the femoral vein, and the largest of the group is embedded in the crural canal. Their afferent vessels are the efferents of the popliteal glands, some of the efferents from the superficial glands of the groin, and the deep lymphatic vessels from the front and outer side of the thigh and knee. Their efferents pass to the external iliac glands.

Lymphatic Vessels of the Lower Extremity.—There are two sets of these vessels, (1) the superficial and (2) the deep.

(1) **Superficial Vessels.**—The superficial lymphatics lie in the subcutaneous tissues. They commence in plexuses which are best marked on the plantar aspects of the toes and foot. The lymphatic vessels which emerge from the plantar plexus in each toe terminate in four digital vessels which are arranged in pairs along the dorso-lateral border of the digit, and these end posteriorly in a plexus on the dorsum of the foot.

Some of the vessels which drain the plexus in the sole of the foot turn round

the outer and inner borders of the foot and join the dorsal plexus, whilst others pass up the leg with the efferent vessels from the dorsal plexus.

The efferent vessels from the dorsal lymphatic plexus of the foot form two groups, an inner and an outer. The inner vessels are the more numerous, and they are joined by additional vessels from the inner part of the sole and heel. Some of them pass upwards in front of and others behind the internal malleolus; in the leg they accompany the internal saphenous vein, and they terminate in the lower or femoral set of superficial glands. The outer group of vessels is reinforced by tributaries from the outer side of the sole and heel, most of the vessels of this group pass upwards in front of the external malleolus, but some go behind that prominence of bone; they gradually turn inwards as they ascend, and, passing across the front of the leg, they join the internal group, being first reinforced by numerous additional vessels from the front and outer side of the leg, and they terminate with the vessels of the inner group in the superficial femoral glands.

A few vessels of the outer group, and one or two large vessels which rise from the back of the heel and the lower part of the leg, ascend along the external saphenous vein, pierce the popliteal fascia, and terminate in the popliteal glands.

The superficial lymphatic vessels from the front, the lower and outer, lower and inner, and the back parts of the thigh and knee, terminate in the superficial femoral glands. The vessels from the upper and outer parts of the thigh and from the buttock end in the superficial inguinal glands, and those from the upper portions of the inner and back parts of the thigh in the superficial pubic glands.

(2) **Deep Vessels.**—The deep lymphatics of the lower extremity commence in the bones, periosteum, ligaments, muscles, and deep connective tissue. They follow the main arteries, and they terminate in the anterior tibial, popliteal, and deep femoral glands.

The vessels which terminate in the anterior tibial gland have already been mentioned.

The majority of the deep vessels from the sole accompany the plantar arteries; they ascend in the leg along the posterior tibial vessels, and are joined by the deep lymphatics of the back of the leg which accompany the peroneal and posterior tibial arteries. At the lower border of the popliteus the deep vessels of the back of the leg meet the efferent vessels from the anterior tibial gland and ascend with them to the popliteal glands.

The deep lymphatics of the front of the thigh and the efferents of the popliteal glands end in the deep femoral glands; those of the upper part of the back of the thigh and buttock accompany the sciatic and gluteal vessels, and terminate in the internal iliac glands; the deep vessels which originate amidst the upper portions of the adductor muscles and their surroundings accompany the obturator vessels, and terminate in the obturator or in the internal iliac glands.

THE LYMPHATIC GLANDS AND VESSELS OF THE ABDOMEN AND PELVIS.

The **superficial lymphatics** of the abdominal wall have already been sufficiently referred to as afferent vessels of the axillary glands and of the superficial glands of the groin.

Deep Lymphatic Glands and Vessels.—The lymphatic glands of the abdomen and pelvis are arranged in two main groups, (1) the visceral glands and (2) the parietal glands. The visceral glands lie in close relation with the walls of the viscera or in the folds of peritoneum, by which the viscera are either connected together or attached to the walls of the abdomen or pelvis; they receive the majority of the lymphatic vessels from the viscera with which they are associated. The parietal glands lie between the peritoneum and the walls of the abdomen and pelvis; they receive deep vessels from the abdominal and pelvic parietes, and from the deep parts of the thigh and buttock. They also receive efferent lymphatics

from the glands of the lower extremities, as well as some of the efferent vessels from the visceral glands, and a few vessels which pass directly to them from the walls of the viscera.

(1) The **visceral glands** include the following:—

Gastric Glands.—These lie along the borders of the stomach in the gastro-hepatic (lymphoglandulæ gastricæ superiores), the gastro-colic (lymphoglandulæ gastricæ inferiores), and the gastro-splenic omenta; they receive afferent vessels from the walls of the stomach, and they give off efferent vessels which terminate in the cœliac glands. The efferents which issue from the glands along the small curvature follow the branches of the coronary artery, those from the glands along the lower part of the great curvature accompany the right gastro-epiploic artery, and the efferents from the glands along the left part of the great curvature, running by the sides of the gastric branches of the splenic artery, pass backwards through the gastro-splenic omentum to the hilus of the spleen, where they join the splenic lymphatics, with which they pass through the lieno-renal ligament to the cœliac glands.

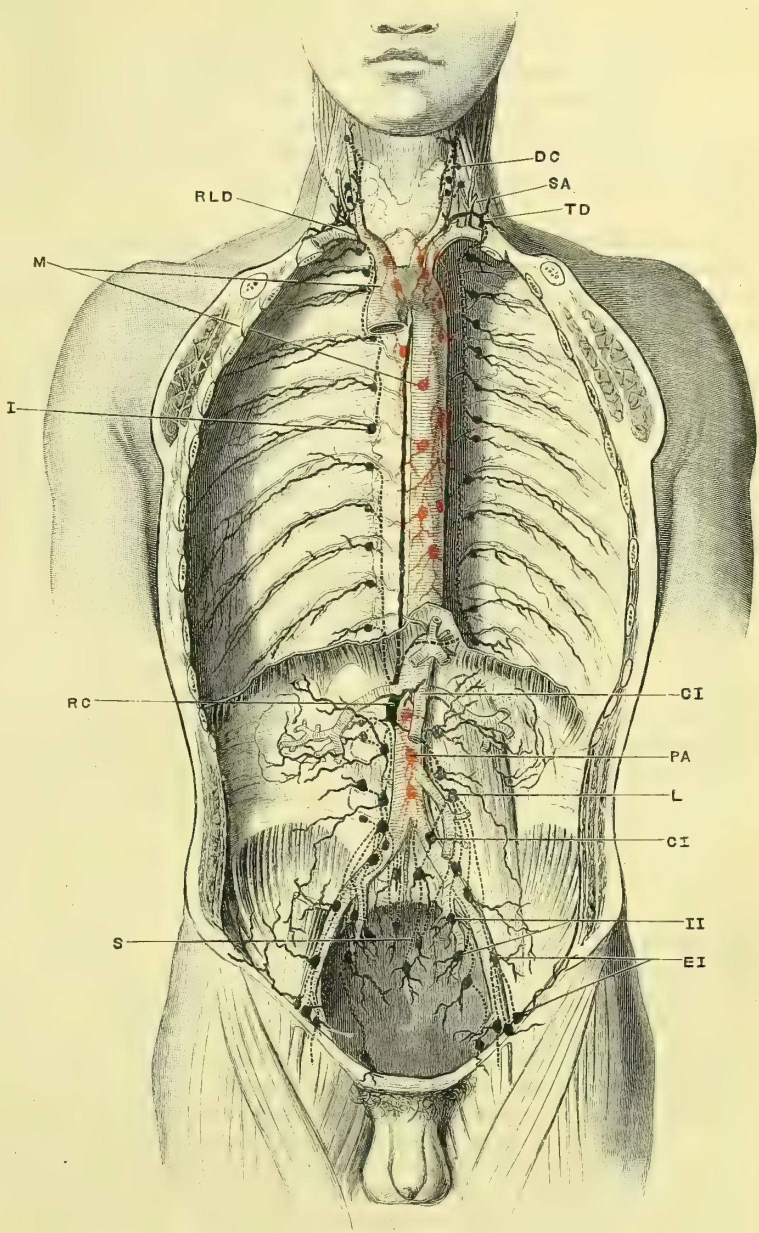


Fig. 596.—Deep Lymphatic Glands and Vessels of the Thorax and Abdomen (diagrammatic).

Lateral lymphatics are coloured black, and mesial red. Afferent vessels are represented by continuous lines, and efferent and interglandular vessels by dotted lines.

C.	Common iliac glands.	M.	Mediastinal glands and vessels.
C.I.	Common intestinal trunk.	P.A.	Pre-aortic glands and vessels.
D.C.	Deep cervical glands.	R.C.	Receptaculum chylii.
E.I.	External iliac glands.	R.L.D.	Right lymphatic duct.
I.	Intercostal glands and vessels.	S.	Sacral glands.
I.I.	Internal iliac glands.	S.A.	Scalenus anticus muscle.
L.	Lumbar glands.	T.D.	Thoracic duct.

The **splenic glands** lie near the hilus of the spleen in relation with the tail

of the pancreas; they receive the lymph vessels from the capsule and from the substance of the spleen. Their efferent vessels, accompanied by some of the lymphatics from the left part of the great curvature of the stomach, pass inwards in the lieno-renal ligament and terminate in the cœliac glands.

The **hepatic glands** (lymphoglandulæ hepaticæ) are situated in the upper part of the small omentum below the transverse fissure of the liver; they receive the deep lymphatics of the liver which accompany the branches of the portal vein, and many of the superficial lymphatics from the under surface of the liver. Their efferent vessels accompany the hepatic artery and terminate in the cœliac glands.

The **pancreatic glands** (lymphoglandulæ pancreaticæ) lie along the upper border of the pancreas behind the small sac of the peritoneum; they receive the lymphatics which issue from the pancreas and from the diaphragmatic glands, and their efferent vessels terminate in the cœliac glands.

The **mesenteric glands** (lymphoglandulæ mesentericæ) are numerous (100 to 200); they are scattered between the layers of the mesentery, and are most numerous in that portion of the mesentery which is connected with the jejunum. They vary in size, but the largest are rarely larger than an almond; the smaller glands lie near the intestine, and the larger near the attached border of the mesentery. They receive afferent vessels from the walls of the jejunum and ileum, and from the ascending colon, the cæcum, and the transverse colon. Their efferents terminate in the pre-aortic glands.

The **ileo-colic glands** are situated in the lowest part of the mesentery near the angle between the ileum and the ascending colon. They receive afferent vessels from the lowest part of the ileum, from the cæcum, and from the vermiform appendix, and their efferent vessels pass, with those of the other mesenteric glands, into the pre-aortic glands. The ileo-colic glands are four or five in number, and occasionally one of them, the *appendicular gland*, is separated from the rest, and is placed in the base of the mesentery of the vermiform appendix. This gland is of special interest, not only because it receives the lymphatics of the appendix, but also because in the female some of the lymphatics of the right ovary terminate in it.

The **colic glands** which lie in relation with the ascending and descending portions of the colon and in the transverse and iliac mesocolic folds of the peritoneum. They receive the lymphatic vessels which issue from the portion of the gut in their immediate neighbourhood, and their efferent vessels terminate in the lumbar and pre-aortic glands.

The **rectal glands** are a few small glands which lie in the meso-rectum; they receive lymphatic vessels from the upper part of the rectum, and their efferent vessels terminate in the lumbar and sacral glands.

The **cœliac glands** (lymphoglandulæ cœliacæ) surround the cœliac axis, and lie in front of the abdominal aorta above the origin of the superior mesenteric artery. They vary in number, and are of large size; they receive the efferent vessels from the gastric, splenic, pancreatic, and hepatic glands, and their efferent trunks unite with the efferents from the pre-aortic glands, and form with them a single trunk, the common intestinal lymphatic trunk, which terminates in the receptaculum chyli.

(2) The **parietal glands of the abdomen and pelvis** are as follows:—

The **external iliac glands** which lie along the front and sides of the external iliac artery. The lower three are just above Poupart's ligament, one lying to the outer side of the artery, one in front, and one to the inner side. The inner of these three receives the efferent lymphatics from the deep femoral glands. The afferents of the anterior gland come from the deeper parts of the lower and the middle portions of the abdominal wall in the area corresponding to the distribution of the deep epigastric artery. The afferents of the outer gland which accompany the deep circumflex iliac artery, are derived from the iliac fossa and from the deeper portions of the lower part of the lateral wall of the abdomen. The higher external iliac glands receive the efferents of the lower glands, and also other vessels from the lateral walls of the pelvis.

The efferent vessels of the external iliac glands pass to the common iliac and to the lumbar glands.

The **obturator gland** is frequently absent. When present it lies at the posterior end of the obturator canal, and is usually small. It receives afferent vessels from the deep parts of the upper and inner portion of the thigh, and its efferents join the internal iliac glands.

The **sacral glands** (lymphoglandulæ sacrales).—This term is applied to several small glands which lie in the concavity of the sacrum, behind the rectum. They receive afferent vessels from the rectum and from the pelvic wall, and their efferents end in the subaortic and lumbar glands.

The **sub-aortic glands** present many variations both in number and in size. They lie in front of the lower lumbar vertebræ, beneath the bifurcation of the aorta. Their afferent vessels come from the pelvic walls and from the sacral glands, and their efferents accompany the efferents of the internal and common iliac glands, to terminate like them in the lumbar and pre-aortic glands.

The **internal iliac glands** are numerous but small. They lie on the lateral wall of the pelvis, in front of the internal iliac artery and the ureter, and in the angle between the internal and the external iliac vessels.

Their afferents are (*a*) the lymphatics, which accompany the gluteal and sciatic vessels from the deep parts of the buttock and back of the thigh; (*b*) the lymphatics from the deep parts of the upper and inner portion of the thigh and the efferents of the obturator gland; (*c*) visceral lymphatics from the lower two-thirds of the uterus, the upper two-thirds of the vagina, the bladder, the seminal vesicle and vas deferens, the prostate and the upper portion of the urethra, and from the root of the penis or clitoris. The efferents of the internal iliac glands terminate either in the common iliac glands, in the lumbar glands, or in the pre-aortic glands.

The **common iliac glands** lie along the sides of the common iliac arteries; they vary both in number and size; in some bodies there may be only two or three small glands, whilst in others there may be several large glands. Their afferent vessels are derived chiefly from the external and internal iliac glands, and their efferents terminate in the lumbar or the pre-aortic glands.

Lumbar Glands.—There are two sets of lumbar glands, (*a*) the lateral and (*b*) the median.

(*a*) The *lateral lumbar glands,* which are of small size, lie close to the transverse processes of the lumbar vertebræ under cover of the psoas muscle; they receive the afferent vessels, which accompany the lumbar arteries, from the deeper portions of the posterior part of the abdominal wall. Their efferent vessels unite with the efferent vessels of the median lumbar glands, and terminate with them, forming a common lumbar lymphatic trunk on each side.

(*b*) The *median lumbar glands* lie along the sides of the aorta and the inferior vena cava. They are numerous and of large size, and they receive afferent vessels (1) from the lumbar portion of the vertebral column and the deeper portions of the posterior part of the abdominal wall in its immediate neighbourhood; (2) from the common iliac glands; (3) from the external iliac glands; (4) from the internal iliac glands; (5) from the lateral lumbar glands; (6) from the kidneys; (7) from the suprarenal bodies; (8) from the testicles or ovaries; (9) from the upper part of the uterus; (10) from the subaortic glands; (11) from the crura of the diaphragm; (12) from the ascending and descending portions of the colon. Their efferent vessels unite with some of the efferent vessels of the lateral lumbar glands, and they terminate in two common lumbar lymphatic trunks, one on each side, which open into the receptaculum chyli.

The **pre-aortic glands** lie in the extra-peritoneal fat in front of the aorta and the inferior vena cava; they receive afferent vessels from the mesenteric glands and from the sub-aortic glands. Their efferents unite with those of the cœliac glands to form a common intestinal lymphatic trunk which terminates in the receptaculum chyli.

Deep Lymphatic Vessels of the Abdomen and Pelvis.—These require no special description. They have already been referred to in describing the deep

glands, and it will be sufficient to say that, speaking generally, they accompany the blood-vessels of the viscera and of the deep portions of the parietes.

THE LYMPHATIC GLANDS AND LYMPHATIC VESSELS OF THE THORAX.

Most of the **superficial lymphatic vessels** of the thoracic wall are tributaries of the axillary glands, and they have already been described; the rest will be included with the afferents of the deep thoracic glands.

Deep Lymphatics of the Thorax.—The glands are arranged in two sets, (1) parietal and (2) visceral.

1. **Parietal glands** include the following:—

The **intercostal glands** (lymphoglandulæ intercostales) which lie in the posterior parts of the intercostal spaces near the heads of the ribs, or a little farther out, between the intercostal muscles. They receive the lymphatic vessels from the deep parts of the posterior portions of the thoracic walls, including the parietal pleura, and their efferent vessels are divided into ascending and descending trunks. The efferent vessels from the intercostal glands of the upper five or six spaces open either separately, or, after uniting into a common trunk on each side, into the right lymphatic duct on the right side, and into the upper part of the thoracic duct on the left side. The efferent vessels from the intercostal glands of the lower four or five spaces unite to form a common trunk on each side, which descends through the aortic opening of the diaphragm and terminates in the receptaculum chyli. Some of them also communicate with the thoracic duct.

The **internal mammary** or **sternal glands** (lymphoglandulæ sternales), which lie along the side of the internal mammary artery, one or two, as a rule, being placed opposite the anterior end of each intercostal space. Their afferents are derived from the deeper parts of the anterior portion of the thoracic wall, from the deep part of the front of the abdominal wall, by vessels which ascend along the superior epigastric artery, from the inner portion of the mammary gland, and from the anterior part of the diaphragm. The majority of their efferents pass to the anterior mediastinal glands, but some of the efferents from the upper sternal glands ascend to the root of the neck, where they join the efferents of the lower deep cervical glands.

The **diaphragmatic glands** lie upon the upper surface of the diaphragm. They are very irregular both in number and size. Their afferent vessels are received from the diaphragm and the upper surface of the liver, and they give off efferents, some of which pass upwards to the anterior mediastinal glands, and others which descend to the pancreatic glands through the aortic orifice of the diaphragm.

2. **Visceral Thoracic Glands.**—Of these there are:—

The **anterior mediastinal glands** (lymphoglandulæ mediastinales anteriores) are embedded in the loose tissue of the anterior mediastinal region. They receive afferents from the middle part of the upper portion of the liver which ascend through the falciform ligament, from the anterior part of the diaphragm, and from the lower sternal glands. Their efferents pass upwards to the superior mediastinum, where some of them enter the superior mediastinal glands, whilst others, continuing upwards, terminate on the right side in the right lymphatic duct, and on the left side in the thoracic duct.

The **superior mediastinal glands** (lymphoglandulæ mediastinales superiores) are grouped round the innominate veins, along the upper part of the aortic arch, and in front of the thoracic portion of the trachea. They receive afferents from the heart, the pericardium, the thymus, and the anterior mediastinal glands. Their efferents terminate at the root of the neck in the right lymphatic and thoracic ducts.

The **posterior mediastinal glands** (lymphoglandulæ mediastinales posteriores) lie along the aorta and the œsophagus in the posterior mediastinum. They receive afferents from the posterior part of the pericardium, the posterior part of the diaphragm, the œsophagus, and from the upper and posterior portion of the liver; the latter vessels accompany the inferior vena cava, and they include the superficial lymphatic vessels of the posterior surface of the liver and the deep lymphatic

vessels which accompany the hepatic veins and their tributaries. Their efferent vessels pass mainly to the thoracic duct, but some of the upper ones on the right side end in the right lymphatic duct, and a few join the bronchial glands.

The **bronchial glands** (lymphoglandulæ bronchiales) lie along the sides of the bronchi, both within and outside the lung. They receive afferents from the superficial and deep parts of the lungs, from the visceral pleura, and from the posterior mediastinal glands. Their efferents pass, on the left side to the thoracic duct, and on the right side to the right lymphatic duct.

The **deep lymphatic vessels of the thorax** have been included in the description of the tributaries of the deep glands. As in the abdomen and pelvis, the main deep lymphatic vessels accompany the blood-vessels of the region.

DEVELOPMENT OF THE BLOOD VASCULAR SYSTEM.

The Pericardium, the Primitive Aortæ, and the Heart.

A general account of the development of the primitive vascular system and of the establishment of the fœtal circulation has been given in a previous chapter (see p. 57 *et seq.*), and it is there pointed out that the earliest blood-vessels of the developing ovum appear in the vascular area of the yolk sac, *i.e.* outside the body of the embryo altogether. Almost simultaneously, however, two longitudinal vessels appear in the embryo itself. They are formed in the splanchnic mesoderm of the pericardial area, and are easily distinguishable before that area is carried downwards to form the ventral wall of the foregut during the evolution of the headfold.

The two longitudinal vessels are the rudiments of the primitive heart and of the principal blood-vessels. The changes which take place in them, and which result in the formation of the fully-developed heart and vessels, will be more easily understood after the development of the pericardial sac, together with the alterations it undergoes both as regards position and relations, have been carefully studied.

Development of the Pericardium and the Primitive Aortæ.—The pericardial area is recognisable as soon as the mesoderm has extended over the embryonic area of the developing ovum. It is somewhat semilunar in shape, it lies at the extreme anterior end of the embryonic region, and it limits the bucco-pharyngeal area or membrane in front and at the sides (Figs. 15 and 18). The mesoderm of the pericardial area is continuous laterally with the general mesoderm of the embryonic area, but in those mammals in which a pro-amnion is formed it is separated in front from the extra-embryonic mesoderm by the pro-amniotic area, whilst in other mammals also it remains quite separate from the extra-embryonic mesoderm in front though it is more closely related to it.

With the formation of the cœlom the mesoderm of the pericardial area is separated into an upper or somatic and a lower or splanchnic layer, and it is in the latter that the two small tubes which constitute the first blood-vessels of the body of the embryo appear. The two tubes, or primitive aortæ, which run longitudinally and parallel to one another, apparently end at first blindly both in front and behind, but as development proceeds they extend backwards, one on each side of the bucco-pharyngeal membrane, beneath the protovertebral somites, to the caudal region, behind which they pass on to the walls of the yolk sac to join the blood-vessels of the vascular area; before ending they give off branches to the allantois. In the human embryo the yolk sac is relatively small and unimportant, and accordingly the branches which go to the allantois, or rather to the chorion along the body stalk, appear to form the more direct posterior continuations of the primitive vessels. The anterior end of each primitive trunk grows outwards along the margin of the pericardial area to its lateral extremity, and is continued on to the yolk sac, where it also joins the vessels of the vascular area.

During the formation and evolution of the headfold the pericardial area increases in size, its cavity enlarges, and both it and the bucco-pharyngeal area are reversed in position (Figs. 16 and 25). Both these areas are carried forwards somewhat with the headfold, in which it is to be remembered the primitive foregut is included, but when the headfold is completely formed the pericardial area lies ventral to the foregut, and its primitive upper somatic surface is now its lower or anterior surface; the original lower or splanchnic surface similarly is superior or dorsal, whilst what was, at first, the anterior border of the pericardial area is converted into the posterior end of the reversed area, and it forms the anterior limit of the umbilical orifice. In brief, the relative positions of its several parts are

reversed, and at this period the pericardial cavity which, like the area, is semilunar in shape, extends from side to side beneath the foregut, and its cornua are continuous at the sides of the foregut with the general body cavity of the embryo. Subsequently this continuity is obliterated, and the pericardial cavity is separated from the pleuro-peritoneal part of the general body cavity or cœlom.

The mesoderm at the posterior end of the reversed pericardial region, where the somatic and splanchnic layers are continuous, *i.e.* just in front of the umbilicus, increases in thickness and forms a semilunar mass, the **septum transversum**, in which the liver and the ventral part of the diaphragm are formed. The latter extends mesially from the anterior wall of the body to the foregut, immediately in front of the gastric dilatation, whilst laterally it forms two falciform projections which encroach from without upon the portions of the cœlom which lie at the sides of the foregut. Ultimately the lateral portions of the diaphragm pass inwards, and, fusing with the mesentery of the foregut, they separate the pleuro-peritoneal portion of the cœlom into three parts—two anterior, one on each side of the foregut, *the pleural sacs*, and a posterior, *the peritoneal cavity*.

When the pericardial region is completely reversed the two vessels developed in its splanchnic layer lie side by side in what is now its dorsal wall. Posteriorly they are continued into the lateral part of the septum transversum, and through it they pass to the wall of the yolk sac. Anteriorly they are continued, as the first cephalic aortic arches, through the mandibular arches which have developed at the sides of the bucco-pharyngeal membrane, to the dorsal wall of the gut, where they pass backwards beneath the paraxial mesoderm and provertebral somites to the posterior end of the body, whence they are continued, in the human subject, along the body stalk to the placental portion of the chorion, giving off branches to the walls of the alimentary canal and yolk sac.

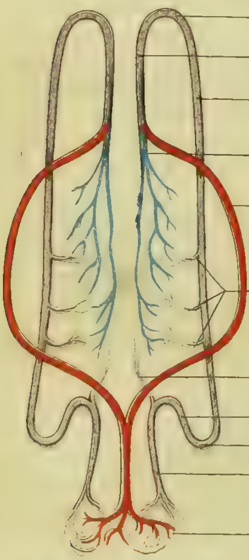


Fig. 597.—Diagram of the Primitive Vascular System before the Formation of the Heart.

These two primitive embryonic vessels are the **primitive aortæ**. After the formation of the cephalic and caudal folds, each primitive aorta may be looked upon as consisting of three parts united by two arches :—an anterior ventral part, the **anterior ventral aorta**, situated partly in the septum transversum and partly in the dorsal wall of the pericardium and the root of the neck ; a dorsal part, the **primitive dorsal aorta**, which extends beneath the paraxial mesoderm from the dorsal end of the mandibular arch to the tail fold ; a posterior ventral part, the **posterior ventral aorta**, which passes to the yolk sac ; the continuation of the posterior ventral aorta to the yolk sac soon atrophies, however, and the vessel is then prolonged from the posterior part of the ventral wall of the body to the placenta by a new branch. The two arches which unite the three main portions of each primitive aorta together are an anterior, the **first cephalic aortic arch**, which lies in the mandibular arch and passes from the anterior ventral aorta to the anterior end of the primitive dorsal aorta, and a posterior, the **primary caudal aortic arch**, which passes in the tail fold and at the side of the hind gut, from the primitive dorsal aorta to the posterior portion of the primitive ventral aorta.

As development proceeds a series of transformations occurs in the various sections of the primitive aortæ. These transformations are, with few exceptions, alike on the two sides, but the transformations which occur in one section are entirely different from those met with in the other sections ; therefore each part must, to a certain extent, be considered separately.

Each anterior ventral aorta is divisible into three parts. The posterior part lies in the septum transversum. Posteriorly it forms the terminal portion of the **vitelline vein**, and carries the blood from the wall of the yolk sac. For a long time it remains separate from its fellow of the opposite side, but afterwards the two vitelline veins unite to form a common stem, which terminates at first in the posterior part of the heart, and subsequently in the liver. The anterior section of the posterior part of the anterior ventral aorta

rapidly enlarges and unites with its fellow of the opposite side to form the **sinus venosus** or posterior chamber of the primitive heart; after a time it grows forwards out of the septum into the pericardium, and is absorbed into the auricular portion of the heart.

The middle part of the anterior ventral aorta lies in the dorsal wall of the pericardium and projects forwards into its cavity. It lies close to its fellow of the opposite side, and as the two vessels rapidly enlarge their inner walls approach each other, and, fusing together, form a single median vessel which constitutes the primitive heart (the sinus venosus being excepted) including the **bulbus arteriosus**, the latter being afterwards developed into the roots of the pulmonary and aortic vessels.

The anterior portion of the anterior ventral aorta is embedded in the tissues at the upper or anterior part of the pericardium, that is, at the root of the neck. At first it is connected with the primitive dorsal aorta by a single cephalic aortic arch, but afterwards three, and eventually four, additional arches connect it with the anterior part of the primitive dorsal aorta. As the neck lengthens this part of the anterior ventral aorta is elongated. For the greater part of its extent it remains separate from its fellow

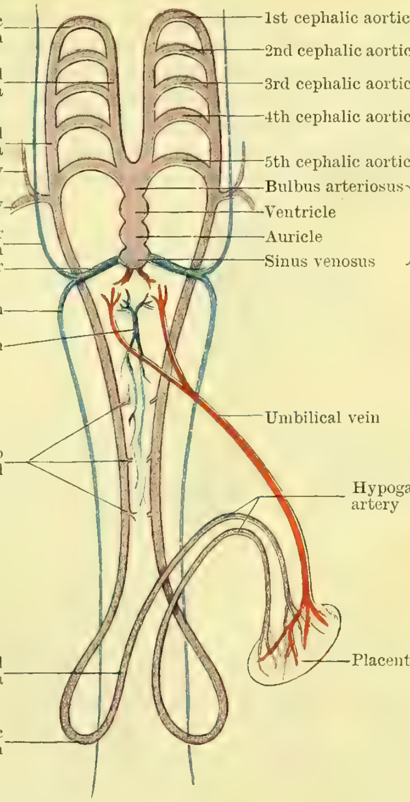


FIG. 598.—DIAGRAM OF THE PRIMITIVE BLOOD-VESSELS AFTER THE FORMATION OF THE HEART.

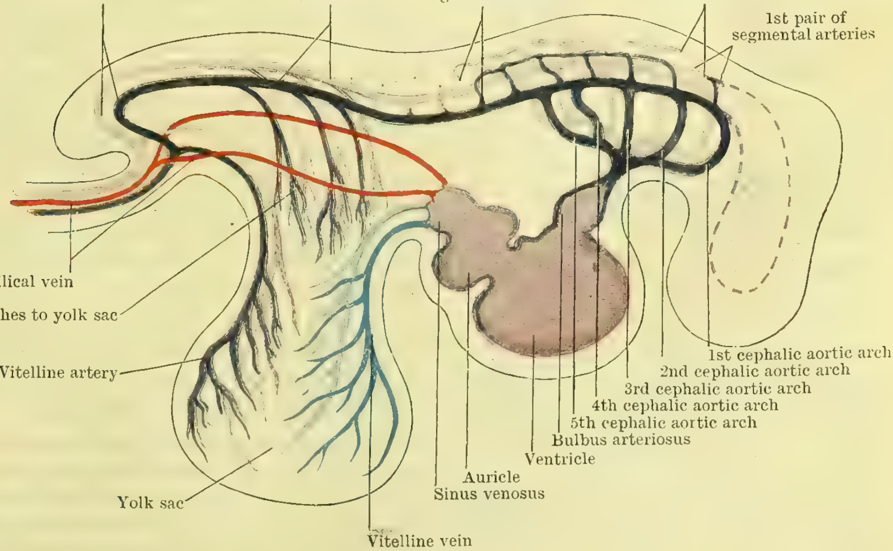


FIG. 599.—DIAGRAM OF THE PRIMITIVE BLOOD-VESSELS AFTER THE FORMATION OF THE HEART, BUT BEFORE ITS SUBDIVISION BY SEPTA INTO AURICLES AND VENTRICLES.

of the opposite side, and it takes part in the formation of the great vessels of the head and neck. Posteriorly, however, it unites with its fellow of the opposite side to form the

apex of the bulbus arteriosus. After the completion of the cephalic aortic arches the portions of the anterior ventral aorta which lie between their lower extremities are known as the **ventral roots** of the cephalic aortic arches.

The primitive dorsal aorta may be conveniently divided into two parts. The anterior part extends from the dorsal end of the first cephalic aortic arch to the root of the fore-limb. It remains separate from its fellow of the opposite side, and forms the **dorsal roots** of the cephalic aortic arches. It takes part in the formation of the great vessels of the head and neck and, on the left side, of part of the aorta of the adult.

The remaining portion extends from the root of the fore-limb to the pelvic region; it passes inwards, and unites with its fellow of the opposite side beneath the vertebral column to form the greater part of the permanent systemic aorta.

The primary caudal arch connects the primitive dorsal with the posterior ventral aorta. As it passes ventrally it lies on the inner side of the Wolffian duct. After a time it is replaced by a **secondary caudal arch** which lies at the outer side of the Wolffian duct, and this subsequently becomes the common and internal iliac arteries and the root of the hypogastric artery, the external iliac being merely an offset from it to the hind-limb.

The greater part of the primitive posterior ventral aorta disappears early, and its secondary continuation to the placenta becomes the remainder of the hypogastric artery, which passes from the internal iliac artery, by the side of the bladder and along the ventral wall of the abdomen, to the umbilicus, whence it is continued along the umbilical cord to the placenta.

Having considered thus briefly the main parts of the primitive aortic vessels, and having noted, shortly, the fate of each portion in the subsequent phases of development, we may now turn to a more detailed consideration of the metamorphoses which occur in those parts of primitive vessels, viz. the anterior ventral aortæ, the cephalic aortic arches, and the anterior parts of the primitive dorsal aortæ, where the transformations are most striking and most complicated, and which result in the formation of the heart, the aorta in part, the pulmonary artery and its primary branches, the chief arterial trunks of the head and neck, and the first part of the main artery of the right upper extremity.

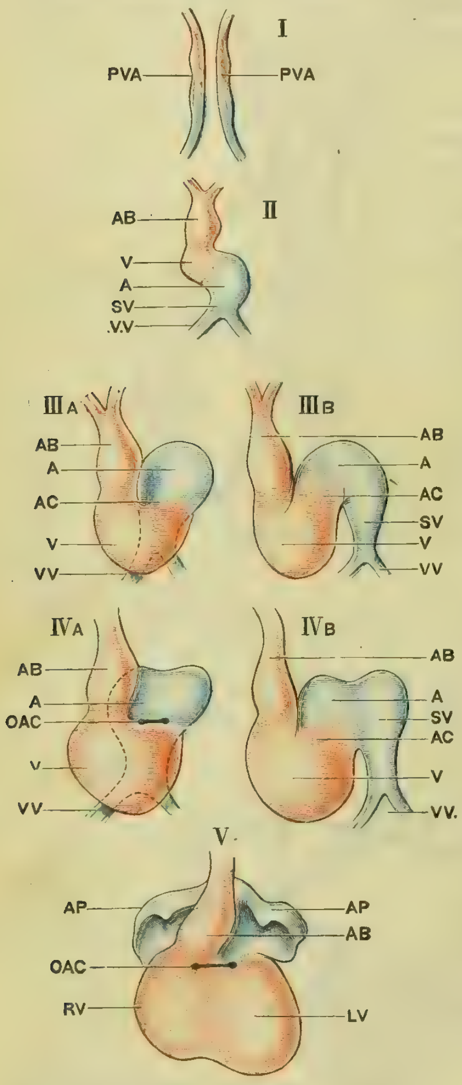


Fig. 600.—Development of the Heart.

Diagram showing the changes of form and external appearances at different stages. Modified from His's models. III.B and IV.B are side views; the other figures represent the heart as seen from the front.

A, Auricle; A.B, Aortic bulb; A.C, Auricular canal; A.P, Auricular appendix; L.V, Left ventricle; O.A.C, Opening of auricular canal; P.V.A, Primitive ventral aorta; R.V, Right ventricle; S.V, Sinus venosus; V, Ventricle; V.V, Vitelline vein.

Development of the Heart, of the first part of the Aorta, and of the Pulmonary Artery.

Of the three parts into which each anterior ventral aorta is divisible the middle is situated in the splanchnic mesoderm of the dorsal wall of the pericardium. As development proceeds the middle parts of both anterior ventral aortæ enlarge and project into the cavity of the pericardium, whilst at the same time they grow inwards, their inner walls come in contact, fuse together, and disappear, and so a simple single median tube is formed. This is the **primitive heart**, which is completed in front

and behind the pericardium by the fusion of the adjacent ends of the anterior and posterior parts of the anterior ventral aortæ respectively.

The simple tubular heart, at first straight and of fairly uniform calibre, soon alters in form and in the relative position of its different parts. It becomes irregularly enlarged, and a series of four dilatations, with intervening constrictions, can be distinguished. The dilatations, from behind forwards, are as follows: (1) the **sinus venosus** or **saccus reuniens,** (2) the **auricle** or **atrium,** (3) the **ventricle,** and (4) the **aortic bulb** or **bulbus arteriosus.** The short constriction between the auricle and ventricle is known as the **auricular canal,** and the less pronounced constriction which intervenes between the ventricle and the aortic bulb is termed the **fretum Halleri.** In addition to this alteration in form, the tubular heart elongates, much more so than the pericardium in which it lies, whilst at the same time the anterior extremity of the aortic bulb and the sinus venosus are withdrawn, from the root of the neck and the septum transversum respectively, into the pericardium. Of necessity, therefore, the single heart is bent upon itself, and it projects more and more into the pericardium, pushing forwards the visceral layer of the serous lining of this cavity, and carrying with it a mesentery of splanchnic mesoderm which is known as the mesocardium.

The bending of the heart results in the formation of a U-shaped loop, the posterior or venous limb of the loop lying to the left and above, the anterior or arterial limb being to the right and below, whilst the intervening stem of the loop runs from the left and above downwards, forwards, and to the right. The apex of the aortic bulb is bent a little to the left and reaches the middle line.

Subsequently the auricle ascends behind the ventricle, and the ventricular opening of the auricular canal, the short communicating passage between the auricle and ventricle, is seen as a transverse slit at the upper part of the left or posterior end of the ventricle. As the ventricular chamber enlarges its anterior end passes towards the middle line, and the ventricle is no longer so obliquely directed from left to right but lies more in the mesial plane. As the result of these changes of position, and the coincident modifications in size of the different parts, the aortic bulb is eventually placed immediately in front of the auricle, and the opening of the auricular canal is nearer the middle of the upper part of the posterior wall of the ventricular chamber. During its further growth the ventricle enlarges principally at its lower or ventral part; the dorsal part is not materially altered in position, and consequently the openings of the auricular canal and the aortic bulb remain relatively at the same level. The auricle increases in size by lateral expansion and by forward extension of its lateral angles; the forward extensions embrace the sides of the aortic bulb, and constitute the rudimentary auricular appendages.

Division of the Heart into its different Chambers, and Division of the Aortic Bulb.

Whilst the changes in form, position, and size of the different sections of the primitive heart, which have just been described, are taking place, the division of the heart cavity into its four permanent chambers, and of the aortic bulb into its aortic and pulmonary portions commences. These divisions are brought about by the growth of **septa** in the ventricle, auricle, and aortic bulb, and by the thickening and fusion of the middle portions of the upper and lower walls of the auricular canal.

The thickenings of the walls of the auricular canal are called **endocardial cushions**; they meet and fuse together mesially to form the **septum intermedium** by which the central portion of the canal is obliterated, whilst the lateral portions are left patent as small triangular channels which still connect the auricular and ventricular chambers.

The separation of the ventricular part of the heart into right and left chambers is indicated, externally, at a very early period, by a groove, well marked in front and below, but less distinct behind where it runs upwards to the auricular canal; whilst internally, in a corresponding position, a **ventricular septum** (s. inferius) grows upwards from the inferior part of the ventricular wall. The posterior part of the upper border of this septum unites with the lower end of the fused endocardial cushions of the auricular canal and the dorsal wall of the ventricle between the auricular and aortic bulb orifices; the anterior part of its upper border terminates a short distance below the orifice of the aortic bulb, where it unites with the septum of the aortic bulb which, at a later period, descends to meet it.

The division of the aortic bulb commences at its distal end between the orifices of the fourth and fifth cephalic aortic arches. It is due to the ingrowth of two endocardial

thickenings which meet and fuse together from their distal to their proximal ends, forming a septum which divides the interior of the aortic bulb into two parts, and then projects downwards into the ventricular chamber till it meets and fuses with the anterior part of the upper border of the ventricular septum. The upper or distal part of the **septum of the aortic bulb** commences from the dorsal wall of the cavity between the fourth and fifth cephalic arches, and it is placed transversely, but its lower end lies more antero-posteriorly, therefore it twists spirally as it descends, and as a result the right part of the ventricle is thrown into continuity with the fifth cephalic aortic arches, whilst the left part of the ventricle retains continuity with the remaining cephalic aortic arches.

After the septum of the aortic bulb is completed, grooves appear along its margins on the surface of the bulb; the grooves deepen until they divide the septum and consequently the bulb into two parts; the part in connexion with the right ventricle and the fifth aortic arch becomes the **pulmonary artery**, and the part in connexion with the left ventricle and the remaining arches becomes the **ascending aorta**.

The separation of the primitive auricle into right and left portions is indicated externally by the appearance of a groove on the upper and posterior wall; opposite this

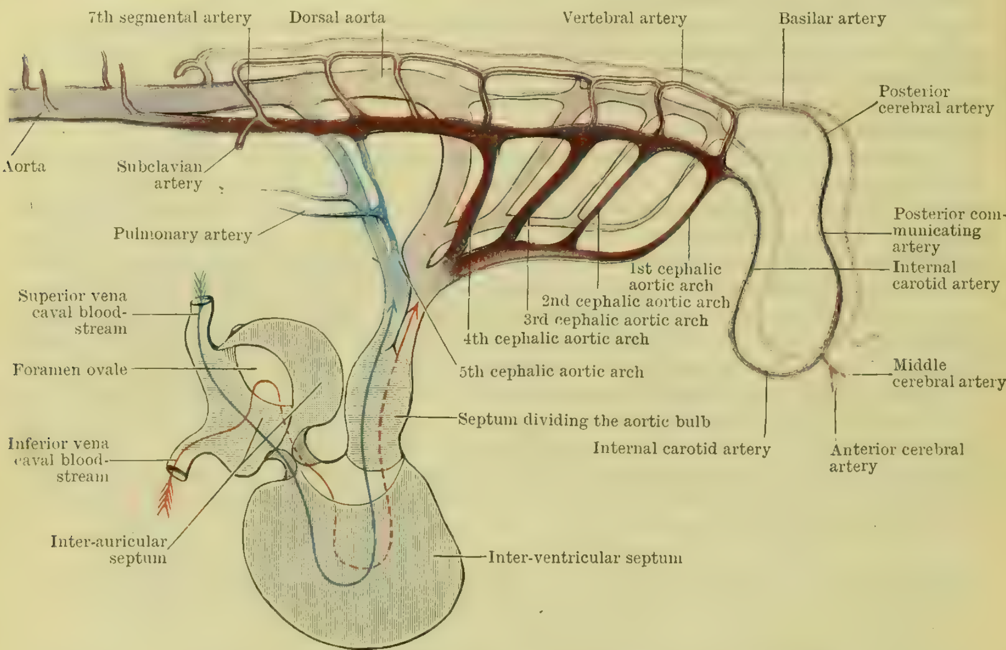


FIG. 601.—DEVELOPMENT OF THE HEART AND THE MAIN ARTERIES.

Diagram of the heart, showing the formation of its septa, and of the cephalic portion of the arterial system.

groove an **auricular septum** grows downwards in the interior of the auricle. Its lower border gradually approaches the endocardial cushion in the auricular canal, and for a time a small opening is left between the upper ends of the fused endocardial cushions and the lower edge of the septum. This is the **ostium primum**; it is closed by the fusion of the septum with the endocardial cushions, but before its closure is completed an aperture appears in the upper part of the septum; this latter aperture, the **ostium secundum**, becomes the **foramen ovale**. A second auricular septum, the *septum secundum*, grows downwards to the right of the first septum; its lower margin grows downwards past the foramen ovale, but stops some distance from the posterior wall of the auricle, and this margin forms the **limbus Vieussenii**, which bounds a fossa, the **fossa ovalis**, in front and below, whilst the floor of the fossa is formed by the *primary septum*, and the foramen which lies at the upper part of the fossa is closed after birth by the fusion of the primary and secondary septa.

The **sinus venosus**, which in the early stages receives the vitelline veins from the yolk sac, the allantoic or umbilical veins from the placenta, and the ducts of Cuvier which return the blood from the Wolffian bodies and the body of the embryo, is the only portion of the primitive heart which is not divided into two parts by the formation of a septum. It lies at first below and behind the auricle, with which it communicates freely,

and it consists of a transverse portion connecting a large right with a small left cornu. Gradually the orifice of communication is constricted, and ultimately it is transformed into a cleft which opens from the right end of the sinus into the back of the right part of the auricular chamber; the cleft is guarded by two lateral valve-like folds of endocardium, the **right** and **left venous valves**, which become continuous above with

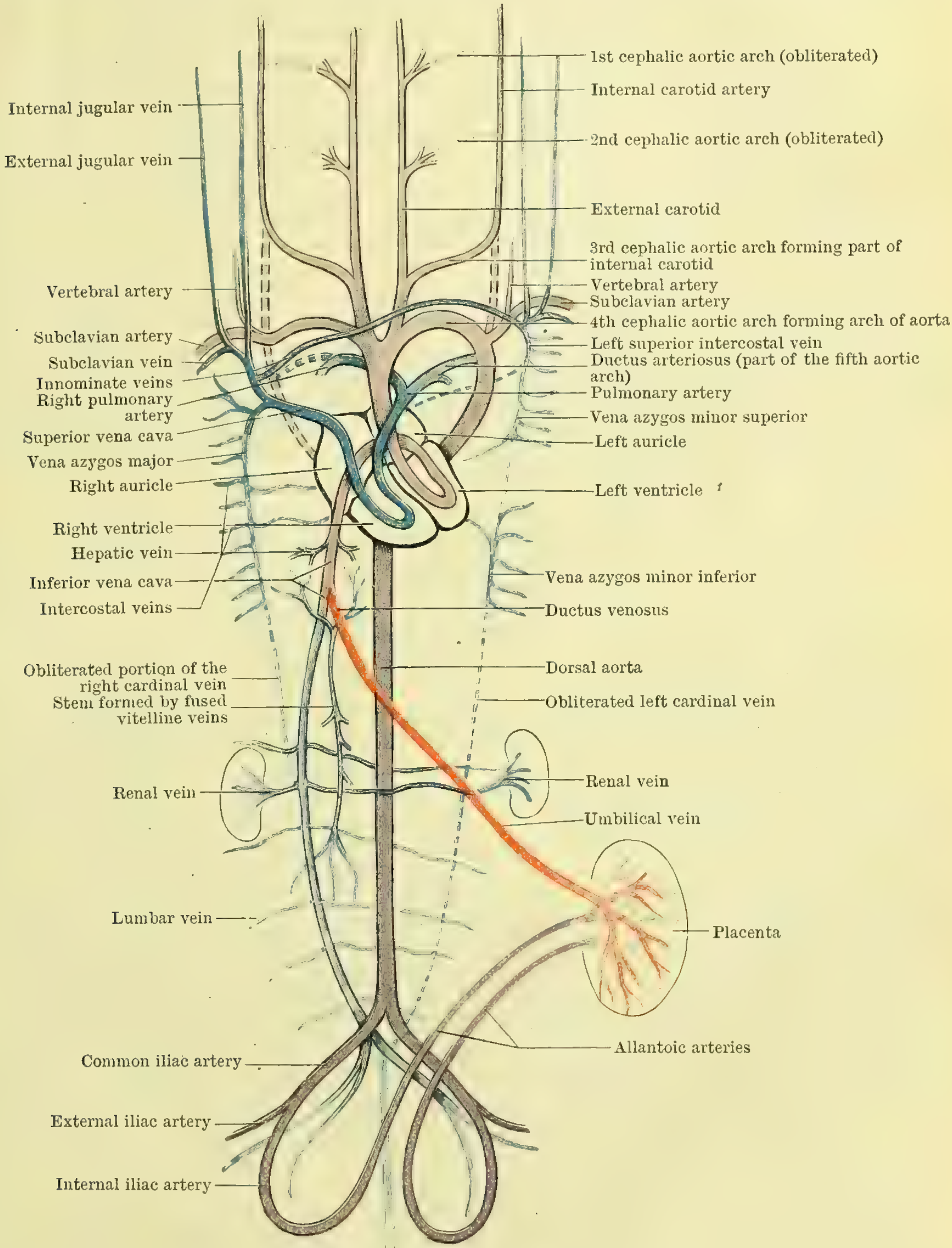


FIG. 602.—DIAGRAM OF THE COURSE OF THE FŒTAL CIRCULATION.

a transitory downward projection from the roof of the auricle, known as the **septum spurium.**

In the early stages the veins of the two sides opened into the corresponding sections of the sinus venosus, but numerous transformations, which are described in the account of the development of the veins, occur, and finally all the veins, except the left duct of Cuvier, open into the right end of the sinus, which is gradually absorbed into the auricular cavity; the transverse part of the sinus, which becomes a mere appendage of the right end, is transformed into the **coronary sinus**, which receives the blood from the walls

of the adult heart; the left end becomes the lower part of the oblique vein of Marshall, the rest of this vein representing the left duct of Cuvier.

Thus, when the development of the heart is completed, all the large veins which reach the heart, with the exception of the pulmonary veins, open into the right auricle, and into that part of the chamber formed by the absorption of the right end of the sinus venosus. Indications of the primitive separation of the auricle from the sinus venosus are still recognisable in the adult, as the **sulcus terminalis** on the exterior, the corresponding **crista terminalis** in the interior, and the **Eustachian** and **Thebesian valves**; the Eustachian valve is a remnant of the upper part of the valvular fold which was situated at the right margin of the slit-like aperture of communication between the sinus venosus and the auricle, whilst the valve of Thebesius represents the lower part of the right venous valve.

The **valves** which guard the auriculo-ventricular orifices are downgrowths from the lower end of the auricular canal. The valves of the pulmonary and aortic apertures are preceded by four endocardial thickenings at the lower end of the aortic bulb—anterior, posterior, and two lateral. As the septum of the bulb descends it fuses with the middle parts of the lateral thickenings; thus, when the septum of the bulb has descended below the lower orifice of the bulb, dividing it into aortic and pulmonary apertures, three endocardial thickenings are found in each aperture, one anterior and two posterior in the pulmonary aperture, and the reverse in the aortic orifice. From these thickenings the semilunar valves of the aortic and pulmonary apertures are developed, and they retain their original positions until after the sixth month of fœtal life; ultimately, however, they are twisted round, so that in the adult the pulmonary valves are placed two in front and one behind, and the aortic one in front and two behind.

The Aortic Arches—Formation of the Chief Arteries.

The aortic arches at the head end of the embryo connect the aortic bulb and the ventral aortæ in front of the bulb, with the corresponding parts of the primitive dorsal aortæ. The arches, ten in number, are arranged in pairs. There are, therefore, five arches on each side, and they are distinguished from before backwards by their numerical designation.

The first is formed during the development of the head fold by the simultaneous bending of the primitive aorta; it lies at the side of the bucco-pharyngeal area, and subsequently in the substance of the mandibular arch. The remaining aortic arches are formed quite differently, and grow dorsally through the substance of the remaining visceral arches, as these are formed in regular succession in the side wall of the pharyngeal portion of the foregut. The second springs directly from the anterior ventral aorta, and passes through the hyoid arch to the dorsal aorta, but the third, fourth, and fifth spring by a common trunk from the apex of the aortic bulb. Subsequently, however, and as the neck grows forwards, the anterior ventral aorta is elongated, and the third and fourth arches arise separately from it. At this later period, therefore, four vessels, two on each side, spring from the aortic bulb, viz. the two fifth arches and the two anterior ventral aortæ from which the anterior four pairs of arches arise. When the septum of the aortic bulb is developed, the bulb is divided into two parts, one (the pulmonary artery) connecting the fifth arches with the right ventricle, and the other (the ascending aorta) connecting the ventral aortic stems, and through them the first, second, third, and fourth pairs of arches, with the left ventricle. Each cephalic aortic arch is connected with the arch immediately behind it by a dorsal root, and in the cases of the first three arches by a ventral root also; but the ventral root of the fourth arch connects it with the aortic bulb. The dorsal and ventral roots of the arches are simply portions of the primitive ventral and dorsal aortæ, which are so named merely for descriptive purposes. From the dorsal roots a series of **segmental branches** are given off, which pass dorsally, between the rudiments of the transverse processes of the cervical vertebræ, to supply the spinal cord and its membranes and the muscles and fasciæ of the back.

The five pairs of arches do not all persist in their entirety, but remains of each are found even in the adult. The first and second pairs disappear almost entirely; from the ventral ends of the first arches, however, the superficial temporal, the internal maxillary, and the lingual arteries are formed; whilst from the ventral ends of the second arches the ascending pharyngeal, posterior auricular, and occipital arteries are derived.

On each side the ventral roots of the first and second arches persist as the stem of the corresponding external carotid artery. The internal carotid is formed by the third arch

together with the dorsal roots of the second and first arches, and is continued forwards to the cerebrum by an outgrowth from the anterior end of the dorsal root of the first arch. The ventral root of the third arch becomes the common carotid artery. The dorsal root of the third arch disappears. On the right side the ventral root of the fourth arch forms the innominate artery, and the arch itself is converted into part of the subclavian artery, whilst the dorsal root disappears. On the left side the ventral root of the fourth arch forms the small portion of aorta which lies between the innominate and left common carotid arteries. The left fourth arch itself and its dorsal root form the arch of the aorta from the origin of the left carotid artery to the attachment of the ductus arteriosus.

The ventral portion of the fifth arch on each side remains as the first part of the corresponding pulmonary artery. The dorsal part disappears early on the right side, but on the left side it persists and remains patent up to birth as the ductus arteriosus. After birth it is obliterated and transformed into a fibrous cord.

The fate of the **primary caudal arches**, their secondary successors, and that of the posterior ventral portions of the primitive aortæ, has already been fully considered (p. 878).

The Primitive Dorsal Aortæ—Formation of the Descending Aorta.

Coincidently with the development of the cephalic aortic arches the anterior portions of the dorsal sections of the primitive aortæ are converted into the dorsal roots of the aortic arches. As already pointed out, certain parts of these disappear entirely, whilst other parts are utilised in the formation of the permanent vessels.

Behind the fifth arches the two primitive dorsal aortæ remain separate as far back as the root of the fore-limb. To this extent the right vessel disappears, whilst the left remains and forms a portion of the descending aorta. From the roots of the fore-limbs backwards to the caudal arches the dorsal aortæ fuse together, beneath the vertebral column, to form the remainder of the descending aorta.

The Branches of the Primitive Dorsal Aortæ.

Each primitive dorsal aorta gives off from its dorsal surface a series of **somatic segmental arteries**, from its sides an irregular series of **intermediate** (visceral) **branches**, and from its ventral surface a group of **segmental splanchnic branches** to the walls of the alimentary canal see (Figs. 609 and 610).

The somatic segmental arteries divide into ventral and dorsal branches which accompany the posterior and anterior primary branches of the spinal nerves respectively, and the ventral branches give off lateral offsets. The various branches of the somatic segmental vessels anastomose freely together.

The splanchnic segmental arteries also anastomose freely together. Ultimately, from the somatic vessels and their branches and anastomoses are developed the vertebral, the basilar, and the spinal arteries, part of the right subclavian artery, the whole of the left subclavian artery, and their continuations in the fore-limbs, the intercostal and lumbar arteries, and the internal mammary and deep epigastric arteries; whilst from the splanchic segmental arteries the majority of the blood-vessels which supply the alimentary canal are developed. The intermediate visceral arteries supply the organs derived from the intermediate cell mass, viz. the suprarenal capsules, the kidney, and the ovaries or testicles; but for a full account of the transformations which the various vessels and anastomoses undergo, reference must be made to the account of the morphology of the arteries.

The Arteries of the Limbs.

Little is known of the precise details of the development of the arteries of the limbs, but there is little doubt that they are formed almost entirely by prolongations of or from somatic segmental arteries or their branches.

The chief arterial stem of each upper extremity is represented by the subclavian, the axillary, the brachial, and the anterior interosseous arteries; these vessels form a continuous trunk which is developed, on the left side entirely and on the right side mainly, from the corresponding seventh somatic segmental branch of the primitive aorta, from its ventral branch, and from the lateral offset of the latter. It is indeed the lateral offset of the ventral branch, growing outwards into the developing limb, which forms the prolongation of the stem.

The root of the right stem vessel, constituted by the right subclavian artery from its

origin as far as the point at which the right internal mammary artery arises, is formed by the fourth right aortic arch; on the left side the fourth arch takes no part in the formation of the subclavian artery.

In the lower limbs the primary main arterial stem, on each side, is represented by the sciatic, the popliteal, and the peroneal arteries. The sciatic artery arises from the caudal arch, and it, together with its prolongation through the popliteal space and leg, is probably formed from a somatic segmental vessel, but to which parts of this it corresponds is not clear. The external iliac artery, prolonged into the limb as the femoral artery, is developed at a later period than the sciatic artery. It arises from the caudal aortic arch above the origin of the sciatic artery, and, like the latter trunk, is probably a modified somatic segmental vessel. The femoral artery soon after its formation unites with the primary main stem, at the upper part of the popliteal space; the sciatic artery then atrophies and loses its connexion with the popliteal artery, and ultimately a permanent chief stem vessel is formed, which includes the external iliac, the femoral, the popliteal, and the peroneal arteries, and obviously it represents the two somatic segmental vessels by which it is formed. Both in the upper and in the lower limb, branches which attain a large size are given off from the main stem artery a short distance beyond the joint between the upper and middle sections of the limb, *i.e.* below the elbow in the upper limb and below the knee in the lower limb, and on account of the relatively great enlargement of these branches the continuity of the original stem is obscured. Thus it is that, in the adult, the brachial artery, the direct continuation of the stem which is divided into subclavian, axillary, and brachial sections, appears to terminate by dividing into the radial and ulnar arteries, whilst originally it was continued through what, in the adult, is the upper part of the ulnar artery to the anterior interosseous artery; the posterior interosseous, the radial, and the ulnar arteries being merely branches from the main stem.

Similarly, in the lower extremity the popliteal artery, which is the continuation of the original stem artery, appears to terminate in the adult by dividing into the anterior and posterior tibial arteries, both of which in reality are branches from the sides of the main stem which was continued as the peroneal artery to the foot.

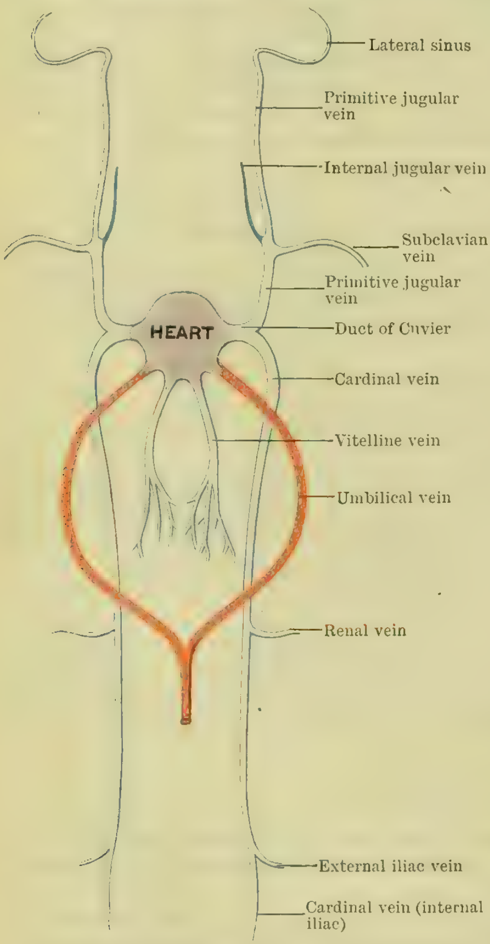


FIG. 603.—DEVELOPMENT OF THE VENOUS SYSTEM (Diagrammatic).

Stage I.—The ducts of Cuvier, the vitelline veins, and the umbilical veins open directly into the heart.

DEVELOPMENT OF THE VEINS.

Simultaneously with the formation of the arteries by which the blood is distributed to the embryo and to the rest of the ovum, and in a similar manner, a series of vessels is developed by means of which the blood is returned to the heart. These vessels are the veins, of which there are two main groups. One group returns blood from the abdominal viscera and the annexa (the yolk-sac and allantois); the other group includes the vessels which return blood from the Wolffian bodies, the body wall, the head and neck, and the limbs of the embryo. The first group consists of the **vitelline, allantoic,** and **portal veins**; the second group includes the **primitive jugular** and the **cardinal veins** and the **ducts of Cuvier.**

The trunks of the vitelline veins are formed by the posterior parts of the anterior primitive ventral aortæ, and necessarily they open into the posterior part of the heart (sinus venosus). They collect blood from the yolk-sac, and ascend along the vitello-intestinal duct to be continued upwards along the

sides of the duodenum. Three transverse anastomoses soon form between them, of which the lower and the upper are in front of and the middle is behind the duodenum; thus two vascular circles are formed round that portion of the gut. Whilst the loops are being formed the liver grows rapidly, and it interrupts the direct connexion of the vitelline veins with the heart. When the upper vascular loop is established the two vitelline veins, which appear to be prolonged from its sides, enter the liver and break up into capillaries, from which two new vessels arise which carry the blood on to the sinus venosus. The veins which carry the blood to the liver are now known as the **venæ advehentes**; they become the right and left divisions of the **portal vein**. The vessels which carry the blood to the sinus venosus are the **venæ revehentes**, and they become the **hepatic veins.**

From the inferior part of the lower venous circle the vitelline veins fuse into a common stem which receives the veins from the abdominal portion of the gut and becomes the commencement of the portal vein. The remainder of the portal vein is formed by the transverse communications previously described, together with the left half of the lower and the right half of the upper circle; the opposite halves of these circles disappear. Thus a continuous single stem is formed, which, after the disappearance of the yolk-sac, receives blood from the abdominal part of the alimentary canal, and terminates above in the liver.

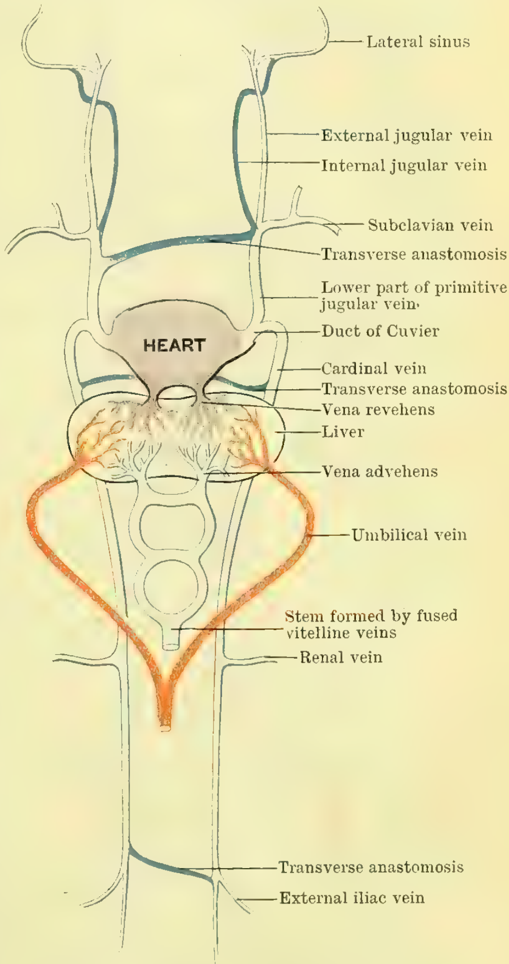


FIG. 604.—DEVELOPMENT OF THE VENOUS SYSTEM (Diagrammatic).

Stage II.—The vitelline and umbilical veins terminate in the liver, and transverse anastomoses have formed between the vitelline, cardinal, and primitive jugular veins of opposite sides.

The allantoic or umbilical veins commence in the placenta and fuse into a single stem which traverses the umbilical cord to reach the embryo, and divides at the umbilicus into right and left divisions. The two veins then pass through the septum transversum, one to the right and the other to the left, and open into the sinus venosus. After a very short period the communications with the sinus are obliterated, and both veins end in the venous capillaries of the liver, the blood they convey now passing to the sinus venosus by the hepatic veins. This condition also is only transitory, for the right vein soon undergoes complete atrophy and disappears, whilst the left opens into the upper loop of the vitelline veins. In the meantime, however, another channel, the **ductus venosus**, has been developed, which passes directly from the upper loop of the vitelline veins, or rather from the left vena advehens to the right hepatic vein, and by this channel the greater part of the placental blood passes to the heart without traversing the liver substance. Some of the placental blood, however, goes to the liver by the left vena advehens. Finally the left vena revehens loses its connexion with the sinus venosus and opens into the right vena revehens. The left umbilical vein and the ductus venosus remain pervious until birth, when the placental circulation ceases. The two vessels then rapidly atrophy, and are subsequently represented by fibrous cords, of which that formed from the left umbilical vein is known as the **round ligament of the liver.**

The primitive jugular and cardinal veins, and the ducts of Cuvier, which constitute the main veins of the Wolffian body and of the body wall, head, neck, and limbs of the embryo, are represented in the adult by the external jugular veins, the whole of the right and part

of the left innominate veins, the superior vena cava, the azygos veins, the left superior intercostal vein, part of the inferior vena cava, the right common iliac vein, a small part of the left common iliac vein, and both right and left internal iliac veins.

The primitive jugular vein of each side returns blood from the head and neck, and corresponding upper extremity, and it terminates below by fusing with the cardinal vein to form a common trunk, the duct of Cuvier, which opens into the sinus venosus. Each cardinal vein returns blood from the body wall, the Wolffian body, and the lower extremity of its own side.

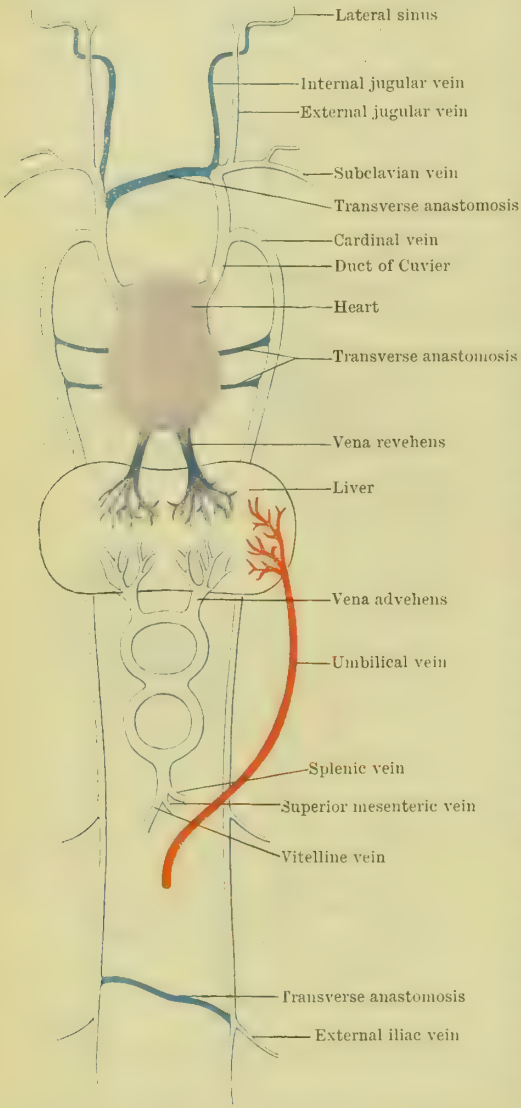


FIG. 605.—DEVELOPMENT OF THE VENOUS SYSTEM (Diagrammatic).

Stage III.—The right umbilical vein has disappeared, and the superior mesenteric and splenic veins have joined the fused vitelline veins.

Numerous transverse anastomoses are developed between the primitive jugular and cardinal veins of opposite sides, and of these four are specially important, one between the primitive jugular veins and three between the cardinal veins; the former becomes the left innominate vein; of the latter, the upper two become the transverse parts of the upper and lower smaller azygos veins, and the third forms the left common iliac vein. As these transverse channels develop, further changes occur in the primitive jugular and cardinal trunks. At first the upper extremity of the primitive jugular vein is in direct continuity with the venous sinuses of the cranium through an aperture, the post-condyloid foramen, in front of the external ear; but this continuity is destroyed, and the aperture in the skull closes as soon as a new vessel, which becomes the internal jugular vein, has grown upwards from a point on the inner side of the primitive jugular trunk and has established a communication with the lateral sinus through the jugular foramen. This vessel rises behind the sterno-clavicular joint, just opposite to, or slightly below, the entrance of the subclavian vein into the outer side of the primitive jugular vein.

With the exception of its upper extremity, the whole of the primitive jugular vein remains on both sides in the adult. On the right side, above the transverse anastomosis between the two primitive jugular veins which becomes the left innominate vein, it forms the external jugular vein, and that portion of the right subclavian vein which intervenes between the external jugular and internal jugular veins and also the right innominate vein; below the anastomosis it forms the upper part of the superior vena cava, the lower part of the latter vessel from the entrance of the vena azygos major downwards representing the right duct of Cuvier, which, though it is placed transversely in the early stages, becomes more vertical as the heart descends in the thoracic cavity. On the left side above the transverse anastomosis it forms the external jugular vein, the innermost part of the subclavian vein, and a small part of the left innominate vein; the main part of the latter vessel being formed, as before stated, from the transverse anastomosis. The portion of the left primitive jugular vein which lies below the anastomosis is represented in the adult by the upper part of the left superior intercostal vein.

The portions of the cardinal veins lying below the transverse anastomosis which becomes the left common iliac vein remain; that on the right forms the right internal and common iliac veins, but the left forms only the left internal iliac vein and a small part of the left common iliac vein, for the transverse anastomosis commences on the left side almost opposite the point of entrance of the external iliac vein, whilst it terminates on the right side at a higher level.

From the left common iliac vein to the renal vein the cardinal vein of the left side disappears; that on the right side becomes the lower part of the inferior vena cava, to which the blood passes from the left side of the abdominal wall by means of small transverse anastomosing channels which existed between the cardinal veins, and which persist as the terminal portions of the left lumbar veins.

Above the renal veins part of the right cardinal vein persists as the vena azygos major, and the left forms the upper and lower minor azygos veins and the lower part of the left superior intercostal vein. The azygos minor veins open into the azygos major by the two transverse anastomosing channels which form between the upper parts of the cardinal veins.

The upper part of the **inferior vena cava** is developed as an outgrowth from the common trunk formed by the fusion of the ductus venosus with the right hepatic vein. It grows downwards, behind the liver and along the right side of the vertebral column, to the interval between the kidneys, where it divides into two branches, of which the right anastomoses with the right cardinal vein at the level of the renal vein; it receives the suprarenal vein, and it terminates in a tapering extremity which is said to become the spermatic vein of the right side. The left branch passes across the front of the aorta below the superior mesenteric artery, and unites with the left cardinal vein at the point of entrance of the renal vein. It gives off an upper branch which becomes the left suprarenal vein, and a lower which becomes the left spermatic vein. As before pointed out, the left cardinal vein disappears between the renal vein and the left common iliac vein, whilst the right remains as the lower part of the inferior vena cava. The left division of the upper part of the inferior vena cava,

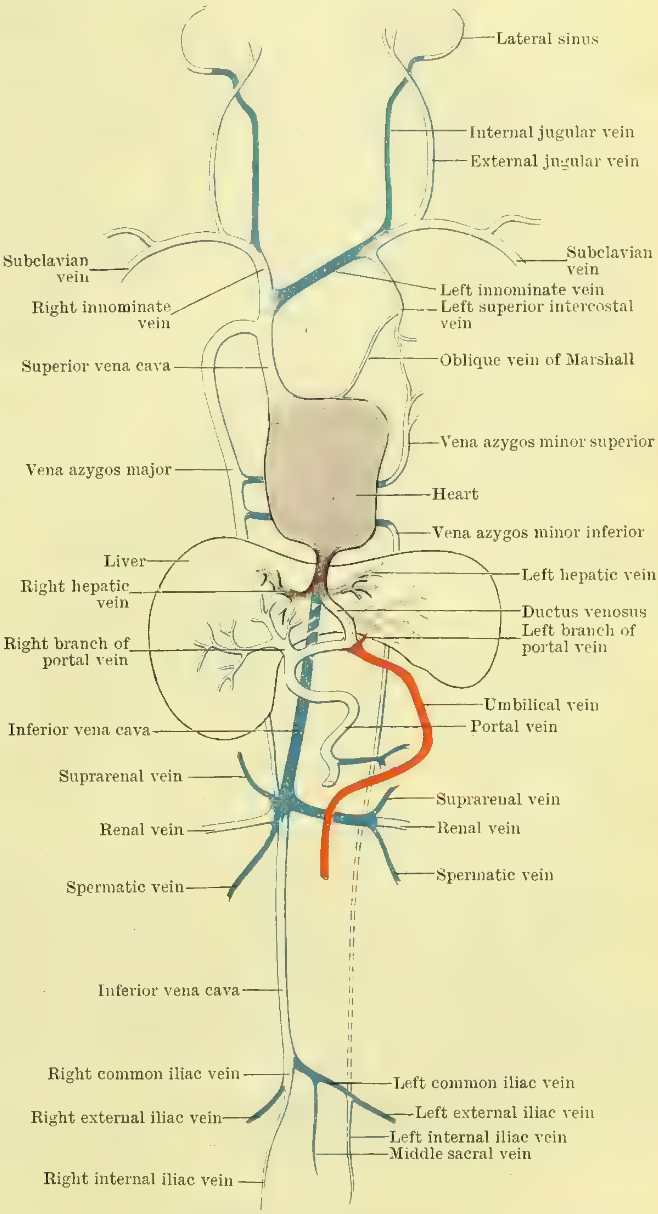


FIG. 606.—DEVELOPMENT OF THE VENOUS SYSTEM (Diagrammatic).

Stage IV.—The left umbilical vein has joined the upper part of the left vitelline vein; the ductus venosus and the upper part of the inferior vena cava have appeared, and portions of the primitive jugular and cardinal veins have atrophied.

which crosses the aorta below the superior mesenteric artery, remains as the inner portion of the left renal vein, which therefore receives the left spermatic and left suprarenal veins as tributaries.

The Veins of the Limbs.

Two sets of veins are developed in each limb, the **superficial** and the **deep**; the former are the primary vessels, and as a rule they are quite apart from the limb arteries; the deep veins are secondary, and they accompany the arteries of the limb.

At the peripheral extremity of each limb a venous arch is developed, which is subsequently transformed into the digital veins. In the upper extremity the arch terminates on the ulnar (post-axial) side of the limb in a trunk which afterwards becomes the posterior ulnar, basilic, axillary, and subclavian veins. At a later period additional superficial vessels are formed, and of these a median vein which drains the palm, and a radial which commences on the radial side of the dorsum of the hand, are the most important. The radial passes up the preaxial border of the limb, becomes the cephalic, and for a time terminates in the primitive jugular vein; this connexion is usually lost,[1] and a new communication is formed with the axillary vein. The median vein ends in an anastomosing vessel between the basilic and cephalic veins at the elbow, and through which it also communicates with the deep veins.

In the lower extremity the peripheral venous arch terminates in a fibular or post-axial trunk, which remains in the adult as the external saphenous vein; its connexion with the sciatic vein, which was its original continuation upwards, is soon lost, and a new communication is formed with the popliteal vein.

The internal saphenous vein is a later development which appears on the pre-axial border of the limb, and terminates in the femoral vein.

The deep veins appear as a series of anastomosing channels at the sides of the arteries.

The Pulmonary Veins.

The pulmonary veins develop simultaneously with the lungs, and at first the veins from both lungs unite to form a single trunk, which enters the left auricle posteriorly, close to the auricular septum; subsequently the single trunk is absorbed, and two veins, one from each lung, enter the left auricle, and eventually, as the result of further absorption, two veins from each lung terminate in that cavity.

MORPHOLOGY OF THE VASCULAR SYSTEM.

In conformity with the general plan of the vertebrate body, the vascular system is essentially segmental in character. This is obvious, even in the adult, in the intercostal and lumbar vessels. It is distinguishable, though less obvious, in the vessels of the head and neck and of the pelvis.

The segmental arteries and veins form a series of bilaterally symmetrical vessels, each of which is united to the vessels of adjacent segments by intersegmental channels, which anastomose with one another, through the portions of the segmental vessels which they connect together, and thus form longitudinal trunks. The longitudinal trunks are clearly secondary, and they are mainly, though not exclusively, intersegmental. From them the main stem vessels of the individual are formed, and from or to these latter the segmental vessels appear to proceed as branches or tributaries.

In the course of development the secondary character of the longitudinal trunks is lost sight of; they become the most important trunks in the individual, and they are formed before the segmental vessels make their appearance.

The Segmental Arteries and their Anastomoses.

The main longitudinal trunks formed by the intersegmental vessels anastomosing with each other, through the segmental arteries which they connect together, are the primitive aortæ. The descending aorta is formed, in the greater part of its extent, by the fusion of the dorsal parts of the primitive aortæ, and from it the segmental arteries arise in pairs.

In a typical segment of the body of the embryo there are three segmental arteries on each side. One rises from the dorsal surface of the primitive dorsal aorta, *i.e.* from the dorsal longitudinal trunk, and runs outwards in the tissues developed from the somatic mesoderm; it is distributed to the body wall, including the spinal column and its contents, and is termed a **somatic segmental artery**. A second vessel rises from the side of the primitive dorsal aorta; it is distributed to the structures developed from the intermediate cell mass, viz. the suprarenal

[1] In certain cases it remains, and then the cephalic vein crosses the front of the clavicle and terminates in the external jugular vein.

body, the kidney, and the ovary or testicle, and it is accordingly termed the **intermediate visceral artery.** The third artery, which is known as the **splanchnic segmental artery,** springs from

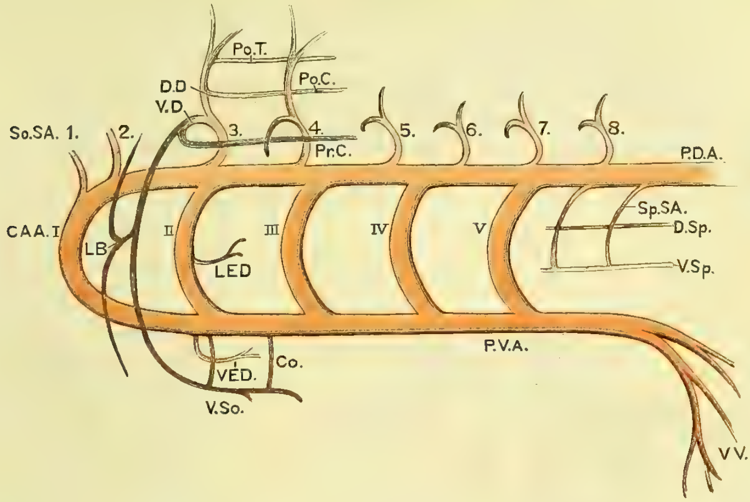


FIG. 607.—DIAGRAM OF THE CEPHALIC AORTIC ARCHES, AND OF THE SEGMENTAL AND INTERSEGMENTAL ARTERIES IN THE REGION IN FRONT OF THE UMBILICUS.

C.A.A I, II, III, IV, V. The cephalic aortic arches.
Co. Anastomosing vessel between the primitive ventral aorta and the ventral somatic anastomosis.
D.D. Dorsal division of a somatic segmental artery.
D.Sp. Dorsal splanchnic anastomosis.
L.B. Lateral branch of ventral division of somatic segmental artery.
L.E.D. Branch to lateral enteric diverticulum.
P.D.A. Primitive dorsal aorta.
Po.C. Post-costal anastomosis.
Po.T. Post-transverse anastomosis.
Pr.C. Pre-costal anastomosis.
P.V.A. Primitive ventral aorta.
So.S.A 1, 2, 3, 4, 5, 6, 7, 8. Somatic segmental arteries.
Sp.S.A. Splanchnic segmental arteries.
V.D. Ventral division of a somatic segmental artery.
V.E.D. Branch to ventral enteric diverticulum.
V.V. Vitelline vessels.
V.So. Ventral somatic anastomosis.
V.Sp. Ventral splanchnic anastomosis.

the ventral surface of the descending aorta. It runs in the tissues developed from the splanchnic mesoderm, and supplies the wall of the alimentary canal.

The **somatic segmental arteries** form in the early embryo a regular series of paired vessels throughout the cervical, dorsal, lumbar, and sacral regions. It is, however, only in the dorsal and lumbar regions that their original characters are retained. The paired vessels pass backwards by the sides of the vertebræ, and divide into dorsal and ventral branches which accompany the corresponding anterior and posterior primary divisions of the spinal nerves.

The **ventral branches** run outwards between the ribs in the dorsal region, and in corresponding positions in the lumbar region. They are connected together, near their commencements, by a series of precostal anastomoses which pass in front of the necks of the ribs, and they are also connected together near their terminations by ventral anastomosing channels which run in the thoracic region behind the costal cartilages, and in the lumbar region behind or in the substance of the rectus abdominis muscle. Each ventral branch gives off a lateral offset which is distributed like the lateral cutaneous branch of a spinal nerve.

The **dorsal branches** run backwards between the transverse processes of the vertebræ; they are connected behind the necks of the ribs by post-costal anastomoses, and again behind the transverse processes of the vertebræ by

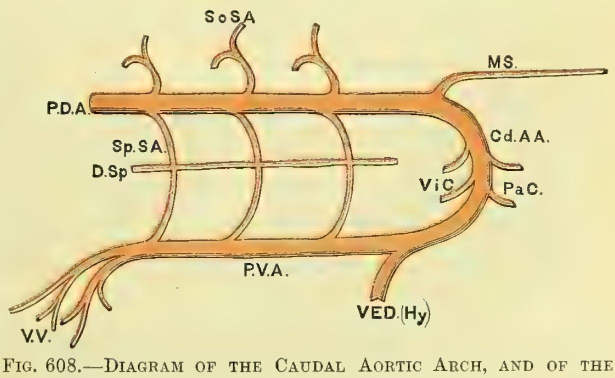


FIG. 608.—DIAGRAM OF THE CAUDAL AORTIC ARCH, AND OF THE SEGMENTAL AND INTERSEGMENTAL ARTERIES IN THE REGION BEHIND THE UMBILICUS.

Cd.A.A. Caudal aortic arch.
D.Sp. Dorsal splanchnic anastomosis.
M.S. Middle sacral artery.
Pa.C. Parietal branch from caudal arch.
P.D.A. Primitive dorsal aorta.
P.V.A. Primitive ventral aorta.
So.S.A. Somatic segmental arteries.
Sp.S.A. Splanchnic segmental arteries.
V.E.D.(Hy). Branch to a ventral enteric diverticulum.
Vi.C. Visceral branch from the caudal arch.
V.V. Vitelline vessels.

post-transverse anastomosing channels. Moreover, each dorsal branch, as it passes by the corresponding intervertebral foramen, gives a spinal offset which enters the spinal canal along the corresponding nerve-root, and divides into a dorsal, a ventral, and a neural branch. The dorsal branches of these spinal arteries are connected together along the ventral surfaces of the laminæ by pre-laminar anastomoses, and the ventral branches are united on the dorsal surfaces of the vertebral centra with their fellows above and below by post-central anastomoses; they are also united with their fellows of the opposite side by transverse communicating channels. The neural branches of the spinal arteries divide similarly into dorsal and ventral branches; the dorsal branches of each side are connected together by post-neural anastomoses, and the ventral branches unite in the middle line both with their fellows above and below and with those of the opposite side, forming a single longitudinal pre-neural trunk.

In the dorsal and lumbar regions of the body the somatic segmental arteries persist and form the intercostal and lumbar arteries. These vessels spring from the dorsal aspect of the descending aorta, usually in pairs. The corresponding vessels of opposite sides, however, occasionally fuse together at their origins, simultaneously with the fusion of the dorsal longitudinal trunks to form the descending aorta, and then they arise by common stems.

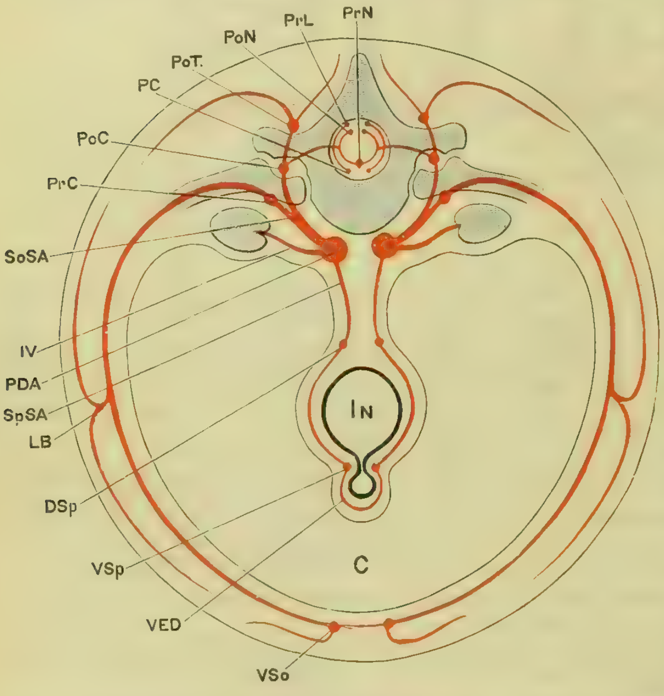


FIG. 609.—DIAGRAM SHOWING THE ARRANGEMENT AND COMMUNICATIONS OF THE SEGMENTAL AND INTERSEGMENTAL ARTERIES AT AN EARLY STAGE OF DEVELOPMENT.

C, Cœlom; D.Sp, Dorsal splanchnic anastomosis; IN, Intestine; I.V, Intermediate visceral artery; L.B, Lateral branch of the ventral division of a somatic segmental artery; P.C, Post-central anastomosis; P.D.A, Primitive dorsal aorta; Po.C, Post-costal anastomosis; Po.N, Post-neural anastomosis; Po.T, Post-transverse anastomosis; Pr.C, Precostal anastomosis; Pr.L, Pre-laminar anastomosis; Pr.N, Pre-neural anastomosis; So.S.A, Somatic segmental artery; Sp.S.A, Splanchnic segmental artery; V.E.D, Branch to a ventral enteric diverticulum; V.So, Ventral somatic anastomosis; V.Sp, Ventral splanchnic anastomosis.

The precostal anastomoses between the ventral branches of the somatic segmental arteries are only represented in the dorsal region by the superior intercostal arteries; in the lumbar region they disappear entirely. The anastomoses between the anterior ends of the ventral branches of the somatic segmental arteries persist as the internal mammary and deep epigastric arteries.

The lateral offsets of the ventral branches are represented by the cutaneous arteries which accompany the lateral cutaneous branches of the spinal nerves.

The post-costal and post-transverse anastomoses usually disappear in the dorsal and lumbar regions, but the post-costal anastomoses occasionally persist in the upper dorsal region, and take part in the formation of the vertebral artery, which in such cases arises from the first or second intercostal artery. In some carnivores the post-costal longitudinal vessels persist in the upper dorsal region, and form, on each side, a trunk which is connected with the first aortic intercostal, and which supplies the five anterior intercostal spaces.

The pre-laminar, the post-central, and the pre- and post-neural anastomoses persist, the two latter aiding in the formation of the dorsal and lumbar portions of the pre- and post-spinal arteries respectively.

It is in the cervical region, however, that the most interesting changes occur. The first six pairs of somatic segmental arteries lose their connexions with the dorsal roots of the aortic arches, *i.e.*, in other words, with the longitudinal anastomosing channels in this region. The seventh pair, however, persist in their entirety; and from them are formed, on the right side, a portion of the subclavian trunk, and on the left side the whole of the subclavian stem from its commencement up to the origin of the vertebral artery. On each side the ventral branch of the seventh segmental artery forms that portion of the subclavian artery which lies between the origins of the vertebral and internal mammary arteries, and also the trunk of the internal mammary artery as far as the upper border of the first costal cartilage. The remainder of the internal mammary artery represents the ventral longitudinal anastomoses between the ventral

branches of the seventh and the following somatic segmental arteries. The continuation of the subclavian artery, beyond the inner margin of the first rib, is the persistent and enlarged lateral offset of the ventral branch of the seventh somatic segmental artery, which is continued outwards into the upper limb behind, or postaxial to the shoulder girdle. The thyroid axis and the superior intercostal artery, both branches of the subclavian artery, are persistent pre-costal anastomoses, and the ascending cervical artery belongs to the same series of vessels. The vertebral artery, which appears as a branch of the subclavian in the adult, is morphologically somewhat complex. The first part represents the dorsal branch of the seventh somatic segmental artery; the second part, that passing through the cervical transverse processes, consists of the persistent post-costal anastomoses between the first seven segmental arteries; a third part, that lying on the arch of the atlas, is the spinal branch of the first somatic segmental artery and its neural continuation; whilst finally the upper part of the vertebral artery, that in the cranial cavity, appears to represent a prolongation of the preneural anastomoses, which still farther upwards are probably represented by the basilar artery. As already stated, the post-costal anastomoses below the seventh segmental artery occasionally persist, and in such cases the vertebral may lose its connexion with the subclavian, and spring from one or other of the dorsal branches of the upper intercostal arteries.

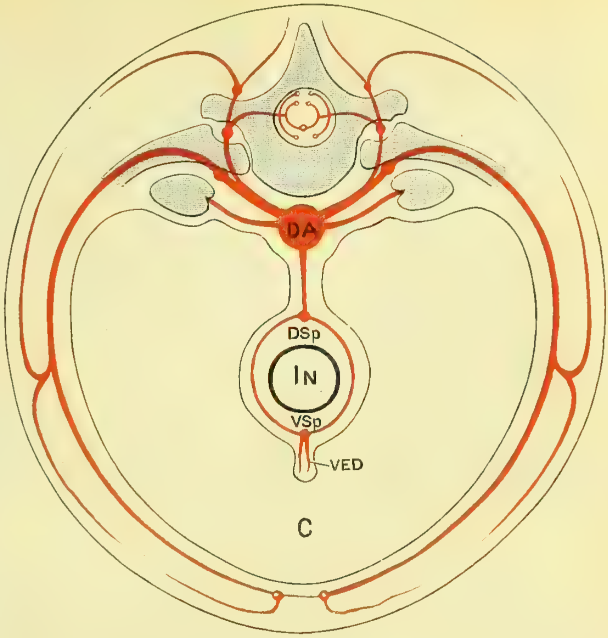


FIG. 610.—DIAGRAM OF THE SEGMENTAL AND INTERSEGMENTAL ARTERIES AT A LATER PERIOD OF DEVELOPMENT THAN IN FIG. 609.

C. Cœlom ; D.A, Dorsal aorta ; D.Sp, Dorsal splanchnic anastomosis ; IN, Intestine ; V.E.D, Branch to ventral enteric diverticulum ; V.Sp, Ventral splanchnic anastomosis.

The profunda cervicis artery is to be regarded as a remnant of the post-transverse longitudinal anastomoses.

The origin of the seventh somatic segmental artery from the dorsal longitudinal trunk is at first some distance behind the fifth aortic arch, but, simultaneously with the elongation of the neck and the retraction of the heart into the thoracic region, it is shifted forward until it is opposite the dorsal end of the fourth aortic arch.

The middle sacral artery is formed by the fusion of two vessels, each of which springs from the primitive aorta in exactly the same manner as a somatic segmental artery; it may therefore be looked upon as consisting of fused somatic segmental vessels which have been prolonged backward for the supply of the caudal appendage. It is, however, commonly regarded as the direct continuation of the descending aorta, and consequently as being mainly intersegmental. Its mode of origin and general nature do not lend much support to the latter view.

The **intermediate visceral arteries** supply the organs derived from the intermediate cell mass. They form a somewhat irregular series of vessels in the adult, but presumably in the

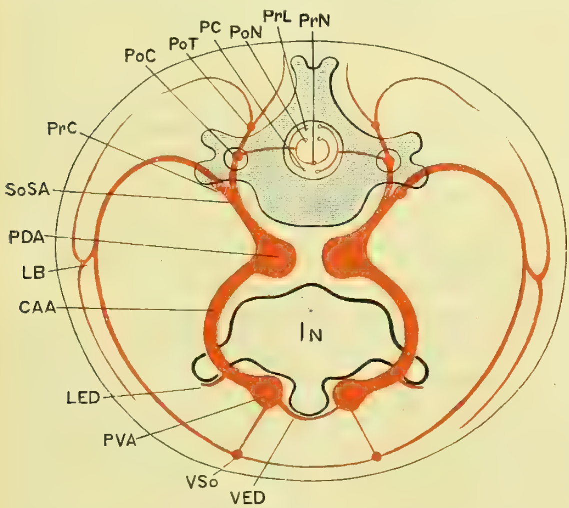


FIG. 611.—DIAGRAM SHOWING THE ARRANGEMENT AND COMMUNICATIONS OF THE SEGMENTAL ARTERIES IN THE REGION OF THE CEPHALIC AORTIC ARCHES.

C.A.A, Cephalic aortic arch ; IN, Intestine ; L.B, Lateral branch of a somatic segmental artery ; L.E.D, Branch to a lateral enteric diverticulum ; P.C, Post-central anastomosis ; P.D.A, Primitive dorsal aorta ; Po.C, Post-costal anastomosis ; Po.N, Post-neural anastomosis ; Po.T, Post-transverse anastomosis ; Pr.C, Pre-costal anastomosis ; Pr.L, Pre-laminar anastomosis ; Pr.N, Pre-neural anastomosis ; P.V.A, Primitive ventral aorta ; So.S.A, Somatic segmental artery ; V.E.D, Branch to a ventral enteric diverticulum ; V.So, Ventral somatic anastomosis.

primitive condition there was a pair in each segment of the body ; many of these disappear, however, and the series is only represented in the adult by the suprarenal, the renal, and the spermatic or ovarian arteries—possibly, also, by some of the branches of the internal iliac arteries.

The **splanchnic segmental arteries** arise in the embryo from the ventral aspects of the primitive dorsal aortæ, and are distributed to the walls of the alimentary canal. They anastomose with their fellows in front and behind in the dorsal wall of the gut; those in front of the umbilicus also communicate together on the ventral wall of the gut, whilst those behind the umbilicus terminate ventrally in the posterior sections of the ventral aortæ.

After the fusion of the dorsal longitudinal trunks to form the descending aorta, the origins of the splanchnic arteries in each segment fuse into a common stem, or either the right or left artery altogether disappears, whilst at a later period the majority of the splanchnic segmental arteries lose their direct connexion with the descending aorta ; those which retain their connexion are the left bronchial arteries, the œsophageal branches of the aorta, the cœliac axis, and the superior and inferior mesenteric arteries, the three latter vessels greatly increasing in size.

The coronary or gastric branch of the cœliac axis, as it passes from its origin to the small curvature of the stomach, represents a right splanchnic artery ; the remainder of the coronary artery and the pyloric branch of the hepatic are remnants of the ventral anastomoses between the splanchnic arteries in front of the umbilicus.

The splenic artery is a branch given off from a splanchnic artery to an organ developed in the gastric mesentery, and the hepatic is a branch from the ventral splanchnic anastomosis to the hepatic diverticulum from the wall of the duodenal portion of the fore-gut.

The superior and inferior mesenteric arteries represent at their origins splanchnic branches, and in the remainder of their extent the dorsal anastomoses on the gut wall.

The Aorta, Pulmonary Artery, and other Chief Stem Vessels.

The heart and the majority of the great arterial trunks of the body, including the aorta, the innominate, part of the right subclavian, the common, external, and greater parts of the internal carotids, the common and internal iliacs, and the pulmonary arteries, are all modified portions either of the primitive aortæ or of the aortic arches. The developmental changes, which result in the formation of the vessels named, are described in the preceding chapter, and the morphology of these vessels is obviously the same as that of the trunks from which they are derived.

It will be sufficient, therefore, to point out that the primitive aortæ are to be regarded as the greatly enlarged pre-central or pre-vertebral longitudinal anastomoses between the successive segmental arteries of each side ; obviously, therefore, each primitive aorta, like the rest of the longitudinal anastomoses, consists chiefly of intersegmental elements. The origins of the segmental vessels only enter into its formation in so far as they connect the intersegmental vessels together, and so complete the longitudinal anastomoses.

The first cephalic aortic arches and the primary caudal arches are simply portions of the primitive aortæ. The other aortic arches have possibly a different morphological significance, but their exact nature is not definitely settled.

The second, third, fourth, and fifth cephalic aortic arches of each side are developed in the undivided mesoderm of the head region behind the first arch. They spring from the anterior part of the primitive aorta which, after the head fold is formed, lies on the ventral aspect of the fore-gut, and they extend at the side of the pharyngeal part of the fore-gut to the dorsal aorta. Thus in some respects they resemble segmental vessels. Behind the umbilicus some of the segmental splanchnic arteries pass from the dorsal to the ventral aorta in the splanchnic mesoderm on the wall of the alimentary canal. In addition to the vessels already mentioned, there are given off from the ventral aortæ and the aortic arches a series of branches which supply ventral and lateral diverticula from the alimentary canal; these are represented in the adult by the superior thyroid, the thyroidea ima, and the terminal branches of the hypogastric arteries.

Iliac Arteries and their Branches.—The common iliac arteries are undoubtedly formed from the primitive aortic longitudinal vessels; they are simply those portions of the right and left primitive aortæ respectively which lie immediately beyond or caudal to the permanent descending aorta. The direct continuation of each is the primary caudal arch, which forms the origin of the superior vesical artery, and is prolonged as the hypogastric artery; these continuous channels are for the most part made up of intersegmental vessels. So also are the permanent vessels into which they are transformed. Reference has already been made to the fact that the primary caudal arch almost entirely disappears, and that a secondary caudal arch is developed in lieu of it (p. 878).

The internal iliac arteries are almost entirely formed from the secondary caudal arches. The primary caudal arch, beyond doubt, is not a segmental vessel; the secondary arch may be, but this is still unproved. The branches of the internal iliac artery which represent offsets of the "caudal arch" portion of the primitive aortæ are arranged in two groups—(1) a visceral set which supplies the walls of the hind-gut and the genital organs, and (2) a parietal set which is distributed to the body wall and to the hind-limbs. The branches distributed to the gut probably represent the segmental splanchnic vessels given off from the dorsal longitudinal vessels; those to the genital organs appear to correspond with the intermediate visceral branches, for they are distributed to organs derived from the intermediate cell mass.

The parietal set are to be regarded as modified somatic segmental branches of the dorsal longitudinal trunks. The lateral sacral arteries which belong to this group represent, in the greater parts of their extent at least, the pre-costal anastomoses.

The Limb Arteries.

In all probability the vessels of both the anterior and the posterior extremities are derived from several somatic segmental arteries, the majority of which, however, in the course of phylogenetic development, have atrophied. The upper limb is supplied in man by the lateral offset from the ventral branch of the seventh somatic segmental artery. It passes out into the extremity behind the shoulder girdle, courses through the upper arm, enters the antecubital fossa, and is continued through the forearm, in the early stages, as the anterior interosseous artery, to the deep part of the palm, where it terminates in the deep palmar arch. At a later period a median artery is given off from the parent stem, and it terminates in a superficial palmar arch; still later the radial and ulnar branches are given off. The latter grow rapidly, soon exceeding in size the parent stem, and they terminate in the superficial and deep palmar arches. The interosseous and median arteries decrease, and generally lose their direct connexions with the palmar arches. The posterior interosseous artery is also a secondary branch from the parent stem, and the digital arteries are offsets from the palmar arterial arches.

The chief arteries of the lower extremities spring directly from the caudal arches, and may be looked upon as being essentially segmental; whether they represent the whole or only parts of typical somatic segmental arteries, however, is not clear.

The arteries of the hind-limbs certainly show no very obvious indications of division into dorsal and ventral branches, though such indications are not entirely wanting. In their comparative absence it is supposed that the dorsal branches have been either suppressed or incorporated with the common stems; that similarly the ventral branches and their lateral offsets are indistinguishably fused, and that probably both are represented in a limb artery.

The original stem vessel of the lower limb is the sciatic artery, which is continued downwards behind the pelvic girdle into the popliteal and peroneal arteries, and so to the plantar arch. Subsequently the external iliac artery is given off from the caudal arch above the origin of the sciatic, and, passing into the limb in front of the pelvic girdle, it becomes the femoral artery. This vessel ultimately unites with the upper part of the popliteal artery, and after this communication is established the lower part of the sciatic atrophies and loses its connexion with the popliteal, which henceforth appears to be the direct continuation of the femoral trunk; therefore, whilst the main artery of the upper limb is formed by the prolongation of the lateral branch of one segmental artery, the corresponding vessel of the lower extremity is developed from representatives of two somatic segmental arteries, the external iliac and femoral trunks being the representatives of one, whilst the popliteal and its continuation, the peroneal, are parts of another.

The first main artery of the leg is the peroneal, which is continued into the plantar arch; after a time, however, the posterior and anterior tibial branches are given off from the stem, over which, as a rule, they soon preponderate in size, and they terminate in the plantar arch, whilst the parent trunk diminishes and loses its direct connexion with the arch.

The peroneal artery corresponds in position and development with the interosseous trunk and the anterior interosseous artery in the forearm. The posterior tibial apparently corresponds with the median artery; it develops in a similar way, and has similar relations to homologous nerves, the posterior tibial nerve representing the combined median and ulnar nerves of the upper extremity.

The anterior tibial artery represents the posterior interosseous, whilst the radial and ulnar arteries of the upper extremity are not represented in the lower limb.

MORPHOLOGY OF THE VEINS.

Two dorsal longitudinal vessels, one on each side, connect the successive segmental veins together. They do not, however, in any part of their course, fuse together to form a single vessel comparable to the descending aorta.

Of these dorsal longitudinal vessels, that on the right side greatly enlarges, and from it the main stem vessels which return blood from the body walls, the head and neck, and the limbs, are almost entirely formed. The left dorsal longitudinal vessel remains relatively small—in parts, indeed, it altogether disappears—and the blood conveyed to it by the corresponding segmental veins is transmitted across the middle line to the chief functional stem by later developed and superadded transverse communicating channels, which are formed between the more primitive longitudinal anastomoses.

The primitive dorsal longitudinal anastomosing channels include on each side (1) the primitive jugular vein, (2) the primitive cardinal vein, and (3) the duct of Cuvier; the last-named vessel, however, is not so much a longitudinal anastomosis as a communicating channel between the longitudinal anastomoses and the heart, for it is formed by the junction of the primitive jugular and cardinal veins, and opens into the sinus venosus of the primitive heart.

From these vessels, and from the transverse communications which are established between the primitive jugular and cardinal veins of opposite sides, the chief veins of the head and neck and the body are formed; there are in addition, however, three later-formed vessels from which some, or portions of some, of the main stem vessels of the body are evolved. These later-formed vessels are the two internal jugular veins and the upper part of the inferior vena cava, whilst from the latter of these portions of the renal veins, the suprarenal veins and the spermatic

or ovarian veins are possibly developed as offsets; moreover, it must not be forgotten that the veins of the extremities are, like the extremities themselves, secondary structures, and that they are developed at a later period than the veins of the trunk, with which, however, they ultimately communicate.

In the light of these facts the morphology of the chief veins of the trunk and limbs may now be considered.

The external jugular vein is obviously a portion of an intersegmental anastomosis, for it is part of the primitive jugular vein, which originally extended from the internal occipital protuberance to the post-condyloid foramen, and thence to the duct of Cuvier. During the course of development the intracranial part of the primitive jugular, on each side, is converted into the horizontal portion of the lateral sinus and the occasionally persistent squamo-petrosal sinus; outside the cranium the trunk of the temporo-maxillary vein, the whole of the external jugular vein, and that portion of the subclavian vein which intervenes between the external and internal jugular veins, are formed from the primitive jugular. On the right side the right innominate vein and the upper part of the superior vena cava are also formed from the primitive jugular vein, whilst on the left side the lower portion of the vessel becomes the upper part of the left superior intercostal vein.

After the formation of the limbs the primitive jugular receives the pre-axial and post-axial veins of the fore-limb of the same side, which pass respectively along the radial and ulnar borders of the limb; both join the primitive jugular vein, the former above and the latter below the clavicle. Subsequently, however, the pre-axial vein of the fore-limb loses its connexion with the primitive jugular vein, and opens below the clavicle into the post-axial vein, and the upper part of that vessel becomes the outer part of the subclavian vein, *i.e.* that portion of the subclavian vein which extends from the outer border of the first rib to the entrance of the external jugular vein, the remainder of the subclavian being formed by the portion of the primitive jugular vein which intervenes between the entrance of the pre-axial vein and the junction with the internal jugular vein.

The internal jugular vein is a newly formed anastomosing vessel which commences from the primitive jugular vein at the root of the neck and grows upwards to the base of the skull, where it passes through the jugular foramen, and ascends along the inner surface of the mastoid portion of the temporal bone to join the lateral sinus, of which it becomes the sigmoid portion. It probably represents a dorsal splanchnic intersegmental venous anastomosis.

The innominate vein of the left side is an enlarged transverse anastomosis between the two primitive jugular veins, and the corresponding vessel on the right side is the portion of the right primitive jugular vein which lies between the origin of the right internal jugular vein and the transverse anastomosis between the two primitive jugular veins.

The superior vena cava is also formed from the primitive longitudinal anastomosis on the right side; the upper portion, which lies above the entrance of the azygos vein, being the lower part of the right primitive jugular vein, and the lower portion, which is enclosed within the pericardium, is the persistent right duct of Cuvier.

The only other vein formed from the jugular portion of the dorsal longitudinal anastomosis is the upper part of the left superior intercostal vein, which represents the part of the left primitive jugular vein lying below the transverse anastomosis which becomes the left innominate vein; occasionally this part of the left primitive jugular vein becomes enlarged, and forms a vertical left innominate vein which terminates in a left superior vena cava, the latter being formed from the left duct of Cuvier. This arrangement is the regular and normal condition in many mammals.

The internal iliac veins, the right common iliac vein, the lower part of the inferior vena cava, the vena azygos major, and the vertical portions of the upper and lower left azygos veins, and part of the left superior intercostal vein, are all parts of the primitive cardinal veins. They represent, therefore, portions of the dorsal longitudinal intersegmental anastomoses.

The internal iliac veins are the persistent lower sections of the cardinal veins, and their visceral and parietal tributaries probably represent more or less modified splanchnic and somatic segmental veins.

The left common iliac vein may, in the lower part of its extent, represent the part of the left cardinal vein immediately above the junction of the pre-axial hind-limb vein with the latter vessel, but the greater part of it is an enlarged transverse anastomosis between the cardinal veins at the level of the pelvic brim. The right common iliac vein, on the other hand, is the portion of the right cardinal vein which lies between the entrance of the limb vein and the transverse anastomosis which becomes the left common iliac vein. The inferior vena cava, from its commencement to the entrance of the renal veins, is a portion of the right cardinal vein, and the right lumbar veins which terminate in it are the somatic segmental veins of the right side of the lumbar region; whilst the left lumbar tributaries are the left lumbar segmental veins, which have been transmitted across the middle line by transverse anastomosing channels which connected the lumbar sections of the cardinal veins together.

The upper part of the inferior vena cava is a new anastomosing channel formed between the upper end of the right hepatic vein and the right cardinal vein. This section of the inferior vena cava grows downwards from the right hepatic vein.

The right and left renal veins originally terminated in the corresponding cardinal veins, and are therefore probably intermediate visceral segmental veins, but that part of the left renal vein which crosses the middle line is either an enlarged transverse anastomosis between the cardinal veins, or an outgrowth from the lower end of the upper part of the inferior vena cava;

apparently the latter, for as the upper section of the inferior vena cava grows downwards from the right hepatic vein it divides into two branches, right and left, each of which joins the corresponding cardinal vein close to the termination of the renal vein. Before it fuses with the cardinal vein of its own side, each of the terminal branches of the upper section of the inferior vena cava gives off branches which ultimately become the suprarenal and spermatic veins; there can be no doubt, however, that both the suprarenal and spermatic veins are intermediate visceral segmental veins, and in all probability they originally terminated in the corresponding cardinal veins, their development from the upper section of the inferior vena cava being due to the production in the embryo of a condition which has been secondarily acquired during the development of the species. If this is the case, it is extremely probable that the left spermatic vein represents not only an elongated intermediate visceral segmental vein, but also a portion of the left cardinal into which it opened.

The vena azygos major is the persistent upper portion of the left cardinal vein, a fact which is emphasised by its frequent connexion with the inferior vena cava at the level of the right renal vein. The right intercostal veins which open into the vena azygos major are somatic segmental veins, the upper three or four of which have united together by pre-costal anastomoses to form a right superior intercostal vein.

The vertical portions of the left azygos veins are remnants of the left primitive cardinal vein, and their transverse portions are enlarged transverse anastomoses comparable to the left innominate and left common iliac veins. The left, like the right intercostal veins, are segmental somatic veins; but whilst the right superior intercostal vein is formed by pre-costal anastomoses between the upper three or four dorsal somatic segmental veins, the left superior intercostal vein (Fig. 606) represents the upper part of the left cardinal vein and the part of the left primitive jugular vein below the transverse anastomosis, which becomes the left innominate vein; moreover, the left superior intercostal vein frequently retains in the adult a connexion with the oblique vein of Marshall, which represents the left duct of Cuvier, by means of which both the left primitive jugular and the left cardinal veins originally communicated with the heart.

Visceral Veins.—The portal vein represents portions of the ventral longitudinal anastomosing vessels, being derived from the vitelline veins.

The pyloric vein is a splanchnic intersegmental ventral longitudinal anastomosing vein. The coronary vein is partly a ventral and partly a dorsal splanchnic intersegmental longitudinal anastomosis, and the superior and inferior mesenteric veins are dorsal splanchnic longitudinal intersegmental venous anastomoses, the splenic vein being merely a tributary from a lymphoid organ developed in the dorsal mesentery.

The facial vein is a combination of somatic and splanchnic veins of several segments, and the internal maxillary vein is probably of similar nature. The thyroid and bronchial veins return blood from organs developed from diverticula from the walls of the alimentary canal; they are, therefore, more or less modified segmental splanchnic veins; so also apparently are the vesical and the middle and inferior hæmorrhoidal veins.

The cardiac veins are simply "vasa vasorum," and they belong therefore to the splanchnic group of vessels, but it is impossible to say whether they are segmental or intersegmental. The coronary sinus into which they open is a portion of the sinus venosus of the heart, and therefore of an originally intersegmental vessel.

The hepatic and pulmonary veins are new vessels which return blood to the heart after the liver and lungs have been interposed in the vascular system.

It is noteworthy that some parts of the splanchnic venous system, *i.e.* the portal vein and the coronary sinus, are portions of the most primitive vascular system, and that others, *i.e.* the thyroid, bronchial, mesenteric, vesical, and hæmorrhoidal veins, appear to belong to a somewhat secondary group of splanchnic veins of combined segmental and intersegmental character; moreover, some of the secondary group of veins open into the primary splanchnic veins, *e.g.* the superior and inferior mesenteric into the portal vein; some open into the dorsal longitudinal anastomosing veins, *e.g.* the vesical and hæmorrhoidal veins open into the cardinal veins, which are intersegmental anastomoses; others again open into an entirely new vein, viz. the internal jugular, which is developed along the dorso-lateral border of the fore-gut, and which is therefore comparable to the dorsal venous splanchnic intersegmental anastomosis, which in the abdominal region becomes converted, after fusion of the vessels of opposite sides, into the greater parts of the superior and inferior mesenteric veins; the latter, however, open into a ventral longitudinal anastomosing vessel, the portal vein, whilst the former joins a dorsal longitudinal anastomosing trunk.

Veins of the Limbs.—The veins of the limbs, like the arteries, were probably at one time segmental in character, but we have no absolute proof that this was the case. Looked at from an embryological standpoint, the most primitive limb veins are a superficial distal arch and a post-axial trunk vein in each extremity; at a later period digital veins are connected with the distal arch, and a pre-axial trunk is formed. In the upper extremity the distal arch and its tributaries remain as the dorsal venous arch and the digital veins, and the post-axial vein becomes the posterior ulnar, the basilic and axillary veins, and also that part of the subclavian vein which lies external to the termination of the external jugular vein, the remainder of the subclavian vein being formed from the primitive jugular vein itself. The pre-axial vein of the upper extremity is represented in the adult by the radial and cephalic veins; the latter vessel originally terminated in the external jugular vein above the clavicle, the union with the axillary portion of the post-axial vessel being a secondary condition; the primary condition is, however, frequently retained in man, and is constant in many monkeys. The anastomosis between the pre-axial

and post-axial veins in the region of the elbow, and the connexion of the anastomosing channels, is brought about by newly-formed vessels of secondary character.

The distal arch in the lower extremity and the tributaries connected with it remain in the adult as the dorsal venous arch of the foot and the digital veins. The post-axial vein becomes the external saphenous vein, which was originally continued upwards as the sciatic vein to the internal iliac portion of the cardinal vein; its connexion with the popliteal vein, and its more occasional connexion with the internal saphenous vein, being brought about by the formation of secondary anastomoses.

The pre-axial vein of the lower limb becomes the long saphenous vein, which is continued upwards to the cardinal portion of the left common iliac vein as the upper part of the femoral and the external iliac veins.

The venæ comites of the arteries in both the upper and lower extremities are secondarily developed vessels which become connected with the upper portions of the pre-axial venous trunks.

ABNORMALITIES OR VARIATIONS OF THE VASCULAR SYSTEM.

Abnormalities are of special interest to the anatomist because of their morphological significance, and the vascular system is, perhaps more than any other, rich in such abnormalities, many of which are of great practical importance.

With the exception of those irregularities which are directly due to the effect of morbid conditions and external influences, all abnormalities are the result of modifications of normal developmental processes. The exceptions referred to are, however, very numerous; thus disease and external influences may lead to the obliteration of vessels, a condition which is invariably associated with the enlargement of collateral vessels, and it will be obvious that abnormalities so produced may occur in almost any situation.

Abnormalities which are determined by, or are dependent upon, modifications of the usual developmental processes are of greater interest. In the human subject they are generally due either to the retention of conditions which normally are only transitory, or to the acquirement of conditions which, though not as a rule present at any time in man, occur normally in other animals.

There are in addition other variations from the normal, such as the division of the axillary artery into radial and ulnar branches; the higher or lower division of the brachial artery; the formation of "vasa aberrantia," *e.g.* of long slender vessels connecting the axillary or brachial to the radial, ulnar, or interosseous arteries; the altered position of certain vessels, as *e.g.* the transference of the subclavian artery to the front of the scalenus anticus, or of the ulnar artery to the front of the superficial flexor muscles; all of which, though undoubtedly due to alterations of ordinary developmental processes, still do not represent conditions met with, either temporarily or permanently, in man or in other animals. Their occurrence cannot at present be adequately explained, and their retention is entirely dependent upon their utility.

To the first and last of these different groups of abnormalities it is not necessary to refer further, whilst with regard to the rest it will be sufficient to indicate those of greatest importance. They can only, however, be fully understood and explained on the basis of a comprehensive knowledge of the development and morphology of the vascular system, to the chapters on which the reader is referred.

ABNORMALITIES OF THE HEART.

The **heart** may be transposed from the left to the right side of the body, a condition which is usually associated with general transposition of the viscera, and with the presence of a right instead of a left aortic arch.

The external form of the heart does not as a rule vary much, but occasionally the apex is slightly bifid, a character it normally possesses at an early stage of its development, and which is retained in the adult in many cetaceans and sirenians. The internal conformation of the heart deviates from the normal much more frequently; more particularly is this the case with regard to the septa which separate the right from the left chambers. The interauricular septum may be entirely absent, as in fishes; it may be fenestrated and incomplete, as in some amphibians; or the foramen ovale may remain patent, as in amphibians and reptiles.

The interventricular septum may be absent, as in fishes and amphibians, or incomplete, as in reptiles; when incomplete, it is usually the "pars membranacea septi" which is deficient.

ABNORMALITIES OF ARTERIES.

The **pulmonary artery** and the **aorta** may arise by a common stem, as in fishes and some amphibians, and the common stem may spring either from the right or the left ventricle, or from both. In these cases the aortic bulb has remained undivided, and the normal position of the interventricular septum in relation to the lower orifice of the aortic bulb has been altered.

Again, owing to malposition of the aortic septum, the pulmonary artery may spring from the left ventricle and the aorta from the right ventricle. In some cases the root of the pulmonary artery is obliterated, and the blood passes to the lungs along the patent ductus arteriosus.

Occasionally the arch of the aorta is on the right side instead of the left, a condition which is normal in birds. More rarely there are two permanent aortic arches, right and left, as in reptiles; the œsophagus and trachea in these cases are enclosed in a vascular collar, the two arches unite dorsally, and the beginning of the descending aorta is double. Quite independent of this condition, however, the two primitive dorsal aortæ sometimes fail, either altogether or partially, to unite together, and the descending aorta is accordingly represented, to a corresponding extent, by two tubes. A more common, though still rare, form of double aorta is that due to the persistence, in whole or in part, of the septum formed by the fused walls of the primitive dorsal aortæ from which the descending aorta is developed.

The length of the descending aorta is determined largely by the extent to which fusion of the two primitive aortæ takes place. Accordingly, when this deviates from the normal, the termination of the descending aorta is at a correspondingly higher or lower level than usual, and resulting from this the lengths of the common iliac arteries are almost invariably proportionately modified. The bifurcation [1] of the aorta may be as low as the fifth lumbar vertebra, less frequently it is higher than usual; it is rare, however, to find it higher than the third or second lumbar vertebra.

The aorta, instead of bifurcating into two common iliac arteries, may terminate in a common iliac artery on one side and an internal iliac artery on the opposite side, the external iliac artery on the irregular side arising, at a higher level, as a branch of the aortic stem. This arrangement approaches the condition met with in carnivores and many other mammals, in which the aorta bifurcates into two internal iliac arteries, the external iliacs arising from the aorta at a higher level as lateral branches; it is due either to a more extensive fusion than usual of the primitive dorsal aortæ, or to the origin of the external iliac arteries from the primitive dorsal aortæ being at a higher level than is ordinarily the case; if the condition is due to the latter cause, it may be that the external iliac arteries in carnivores, and the external iliac arteries which occasionally rise from the aorta in man, are somatic segmental arteries of a higher segment than the normal external iliac arteries of the human subject.

The Branches of the Aorta.

The **coronary or cardiac arteries** may arise by a single stem. When arising separately both may spring from the same sinus of Valsalva; or again, their interventricular and transverse branches may all arise as distinct vessels from a single sinus of Valsalva. This variability is not so remarkable, seeing that the arteries in question are merely enlarged "vasa vasorum" raised to a position of special importance by the development of the heart.

The **branches of the arch of the aorta** are sometimes increased and sometimes decreased in number.

The highest number recorded is six, viz. right subclavian, right vertebral, right common carotid, left common carotid, left vertebral, and left subclavian. Apparently this condition is the result of the absorption of the innominate artery and of the roots of the subclavian arteries, to points beyond the origins of the vertebrals, into the arch. By variations of this process of absorption other combinations may be produced; thus, instead of the roots of the subclavian arteries being absorbed, the right common carotid and innominate arteries may alone be absorbed, in which case the five following branches spring separately from the arch of the aorta: right subclavian, right external carotid, right internal carotid, left common carotid, and left subclavian. The trunk most commonly absorbed is the initial part of the left subclavian; the number of branches then arising from the arch of the aorta is four, the additional vessel being the left vertebral, which arises between the left common carotid and the left subclavian. Occasionally the usual three branches from the arch are increased to four by the formation of a new vessel, the "thyroidea ima." This may be placed between the innominate and left carotid trunks, in which case it represents a persistent ventral visceral branch from the ventral root of the fourth left aortic arch; in other cases the thyroidea ima springs from the innominate artery and represents a ventral visceral branch of the ventral root of the fourth *right arch*. Very rarely the right vertebral artery arises separately, and forms a fourth branch of the arch of the aorta, the rest of the branches being normal. This condition cannot be accounted for by any modification of the ordinary developmental processes. It may possibly be due to the persistence of an irregular or unimportant anastomosis between the ventral root of an aortic arch and the seventh somatic segmental artery.

Decrease in the number of branches from the arch of the aorta is most frequently due to fusion of the ventral roots of the fourth aortic arches, the result being that a stem is formed common to the right subclavian and the right and left common carotid arteries; whilst the left subclavian, arising separately, is the only other branch which springs from the arch of the aorta.

If the fusion of the ventral roots proceeds further and includes those of the third arches, the result as regards the branches given off from the arch of the aorta is the same, viz. there is a common stem for the right subclavian and both carotids, and a separate left subclavian trunk; but

[1] It is to be observed that the exact point of bifurcation of the aorta, in relation to the vertebral column, is not entirely determined by the length of the descending aorta.

the common stem now gives off the right subclavian artery, and then continues as a single vessel for some distance before it divides into the two common carotids, of which the left crosses in front of the trachea. This arrangement is common in many quadrumana and in some other mammals.

It is only very occasionally when the number of branches from the arch of the aorta is reduced to two, that these consist of a right subclavian artery and of a single stem common to the two carotids and the left subclavian arteries. In such cases, however, the right common carotid crosses in front of the trachea, and the variation is one of practical importance. It does not appear to exist as a normal condition in any mammal. Probably it is due to fusion of the ventral roots of the fourth aortic arches, with absorption of the left fourth arch and the left subclavian into the stem so formed, whilst the right subclavian is relatively displaced. The two common carotids may arise by a common stem, and the left subclavian arise separately from the arch of the aorta, whilst the right subclavian springs from the descending aorta. This arrangement probably results from the disappearance of the fourth right arch and the fusion of the ventral roots of the fourth arches of opposite sides.

Sometimes two innominate arteries, right and left, replace the three usual branches of the arch of the aorta. This is the normal arrangement in bats, moles, and hedgehogs. It is obviously the result of the disappearance of that portion of the arch which intervenes between the left carotid and left subclavian arteries, and the consequent fusion of these two vessels.

In a similar way may be explained the rarer condition in which the three ordinary branches of the arch arise by one single stem, which divides into right and left innominate arteries. In most ruminants, in the horse and in the tapir, this arrangement is constant.

It will be evident that other combinations and modifications may be met with in the branches of the arch of the aorta as the result of fusions and absorption.

The **bronchial arteries** obviously correspond to splanchnic segmental arteries and their continuations to diverticula from the walls of the gut, therefore the usual origin of the right bronchial artery from the first right aortic intercostal artery must result from the persistence of an anastomosis between a splanchnic segmental artery and the first part of a somatic segmental artery; the origin of the right from the upper left bronchial artery, which sometimes occurs, is due to the fusion of the roots of two splanchnic segmental arteries. The occasional origin of a bronchial vessel from an internal mammary artery can only result from the persistence and enlargement of an anastomosis between a splanchnic segmental artery and the ventral branch of a somatic segmental artery. The origin of a bronchial branch from a subclavian artery may have the same or a different significance on opposite sides of the body. A bronchial artery arising from the left subclavian artery corresponds with the origin of the right bronchial artery from the first aortic intercostal artery; it is due to the persistence of an anastomosis between a splanchnic segmental artery and the root of a somatic segmental artery, and the origin of a bronchial artery from a right subclavian artery may be due to a similar cause. It may, on the other hand, be due to the enlargement of an anastomosis between a splanchnic branch of the descending aorta and a splanchnic branch of the fourth right aortic arch. When, as occasionally happens, the bronchial artery arises from the inferior thyroid, it is due to the persistence and enlargement of an anastomosis between splanchnic arteries.

Intercostal Arteries.—Variations of the intercostal arteries are not very common, but they are significant and interesting. Corresponding vessels of opposite sides may arise from a common stem which has been formed by the fusion of the roots of two somatic segmental arteries after or simultaneously with the fusion of the primitive dorsal aortæ. The number of intercostal arteries may be reduced, one artery supplying two or more intercostal spaces; in these cases the roots of origin of some of the somatic segmental arteries in the dorsal region have disappeared, and the precostal anastomoses between their ventral branches have persisted.

Occasionally the number of the aortic intercostal arteries is increased, an additional artery being given to the second intercostal space, which is usually supplied by the superior intercostal artery; this is brought about by the persistence of the root of the tenth somatic segmental artery and the disappearance of the precostal anastomosis between the ventral branches of the ninth and tenth somatic segmental arteries. Very rarely the first aortic intercostal artery sends a branch upwards between the necks of the ribs and the transverse processes of the upper dorsal region; this branch supplies the upper intercostal spaces, the superior intercostal artery being small or absent, and it terminates by becoming the profunda cervicis artery. It is due to the persistence of the postcostal anastomoses in the upper dorsal region, and is a repetition of a condition regularly present in some carnivores.

There are no very important variations of the œsophageal, pericardial, and mediastinal arteries.

Lumbar Arteries.—Variations of the lumbar arteries are very similar to those of the intercostal arteries, and they are due to similar causes. The lumbar arteries of opposite sides may arise by common stems from the back of the aorta; and the last pair of lumbar arteries may arise in common with the middle sacral artery. Further, a lumbar artery may have its area of distribution increased to the adjacent segment.

The **inferior phrenic arteries** are very variable; they may arise by a common trunk either from the cœliac axis or from the aorta; they may arise separately either from the aorta or from the cœliac axis, and more commonly from the latter vessel; or again, one may spring from the aorta or cœliac axis, and the other from the coronary, renal, or even from the superior mesenteric artery.

The **middle sacral artery** usually springs from the back of the aorta above its bifurcation;

it may be considerably above, or more rarely it may spring directly from the bifurcation. Not infrequently it arises from the last lumbar artery or from a stem common to the two last lumbar arteries, and occasionally it arises from a common or internal iliac artery. Sometimes it apparently gives off the last pair of lumbar arteries, and very occasionally an accessory, renal, or a hæmorrhoidal branch arises from it. The vessel is not always present, it may be double, entirely or in part, and it may bifurcate at its termination.

The **renal arteries** frequently deviate from the normal arrangement. The arteries of opposite sides may spring from a common stem, or there may be two or more renal arteries on one or both sides. The accessory arteries are more common on the left than on the right side, and an accessory artery rising above the ordinary vessel is more common than one rising below it.

Accessory renal arteries may be derived not only from the aorta, but also from the common or internal iliac arteries; they have also been described as arising from the inferior phrenic, spermatic, lumbar, or middle sacral arteries, and even from the external iliac artery. As the kidney is developed in the region of the first sacral vertebra, and afterwards ascends to its permanent position, it is not surprising that it occasionally receives arteries from the main stem of more than one of the segments of the body through which it has passed, and it is usually found that the lower the position of the kidney in the abdomen the more likely it is to receive its arteries from the lower part of the aorta or from the common iliac arteries. The accessory renal arteries which spring from the inferior phrenic, the spermatic, and lumbar arteries can only be the result of the persistence and enlargement of anastomosing channels between the renal and either another intermediate visceral, or a somatic artery.

The **spermatic or ovarian arteries** may be double on one or both sides; the arteries of opposite sides may spring from a common trunk, or they may rise from the renal or suprarenal arteries. The right artery may pass behind instead of in front of the inferior vena cava. The spermatic and ovarian arteries arise from the upper lumbar portion of the aorta, because the testicles and ovaries are developed in and obtain their arterial supply in that region, and the vessels are elongated as the testicles and ovaries descend to their permanent positions. The occurrence of two spermatic arteries on one side is probably an indication that the testicle was developed in at least two segments of the body, and the origin of a spermatic artery from a renal or suprarenal artery is due to the obliteration of the root of the original vessel and the enlargement of an anastomosis between the intermediate visceral arteries of adjacent segments.

The **cœliac axis** may be absent, its branches arising separately from the aorta or from some other source. Sometimes it gives off only two branches, usually the coronary and splenic, and occasionally it gives four branches, the additional branch being either a second coronary artery or a separate gastro-duodenal artery.

The **hepatic artery** may spring directly from the aorta or from the superior mesenteric artery, and the left hepatic artery occasionally arises from the coronary artery. Accessory hepatic arteries are not uncommon, and they originate either from the coronary, superior mesenteric, renal, or inferior mesenteric artery.

The **coronary artery** is occasionally double; it may spring directly from the aorta, and it may give off the left hepatic or an accessory hepatic artery.

The **splenic artery** may arise from the middle colic, from the left hepatic, or from the inferior mesenteric artery.

The **superior mesenteric artery** may be double, and it may supply the whole of the alimentary canal from the second part of the duodenum to the end of the rectum, the inferior mesenteric artery being absent. In addition to its ordinary branches it may give off a hepatic, a splenic, a pancreatic, a gastric, a gastro-epiploic or a gastro-duodenal branch. Very rarely it gives off an omphalo-mesenteric branch, which passes to the region of the umbilicus and becomes connected with capillary vessels in the falciform ligament of the liver.

The **inferior mesenteric artery** may give hepatic, renal, or middle colic branches; occasionally it is absent, being replaced by branches of the superior mesenteric, and sometimes, as in ruminants and some rodents, its left colic branch does not anastomose with the middle colic artery.

All these variations of the unpaired visceral branches of the abdominal aorta are merely due to modifications of the usual processes by which these vessels are developed.

The origin of the branches which usually rise from the cœliac axis, from the trunk of the aorta is the result of the retention of a greater number of the splanchnic segmental arteries than usual. A double superior mesenteric artery results from the persistence of both the right and left splanchnic vessels from which the superior mesenteric artery is formed, these remaining separate instead of fusing together. All the other variations are the results of the obliteration of the usual channels, combined with the enlargement of anastomoses which exist both between the splanchnic arteries of adjacent segments and the splanchnic and intermediate visceral arteries.

The Arteries of the Head and Neck.

Innominate Artery.—From what has already been said with reference to the branches of the arch of the aorta, it will be seen that the innominate artery may be absent. On the other hand there may be two innominate arteries, a right and a left, each ending in corresponding common carotid and subclavian trunks, and the two vessels may themselves arise by a common stem.

The branches given off by the innominate artery may be increased in number, or the innominate may only vary from the normal as regards length. As a consequence of such modifications in length, the origins of the right common carotid and right subclavian arteries may be situated at a higher or lower level than usual, whilst, in the absence of the innominate artery, both these branches may arise directly from the aorta.

Common Carotid Arteries.—When the right common carotid artery arises separately from the arch of the aorta, it may be the first, or much more rarely the second branch. In the former case the fourth right aortic arch has been obliterated, and the right subclavian artery springs from the descending aorta; in the latter case either the innominate stem has been absorbed into the arch of the aorta, or the ventral root of the fourth right aortic arch has fused with part of an elongated fourth left arch.

Whether arising as the first or second branch, the origin may be to the left of the mesial plane, and the trunk may pass in front of the trachea, or behind the œsophagus, before it ascends in the neck.

The left common carotid artery varies as regards its origin much more frequently than the right vessel; not uncommonly, and apparently because of the fusion of the ventral roots of the fourth aortic arches, it arises from a stem common to it and to the right common carotid and right subclavian arteries.

Both common carotids may vary as regards their termination. They may divide at a higher or lower level than usual, the former more commonly than the latter; whilst in a few exceptional cases the common carotid does not divide, but is continued directly into the internal carotid, and from this the branches usually given off by the external carotid are derived.

This arrangement is probably due to obliteration of the ventral roots of the first and second aortic arches, the arches persisting and being divided into the branches which generally arise from their ventral extremities.

Usually the common carotids give off no branches, but not infrequently one or more of the branches of the external carotids arise from them.

The **external carotid artery** may be absent, or it may, in rare cases, arise directly from the arch of the aorta. The number of its branches may be diminished either by fusion of their roots or by transference to the internal or common carotid arteries. On the other hand, the number of its branches may be increased; thus the sterno-mastoid artery, the hyoid branch usually given off by the superior thyroid artery, or the ascending palatine branch of the facial, may arise from it. Sometimes the branches may arise in the usual way, but may deviate from the course generally taken; more particularly is this the case with the internal maxillary artery, which may pass either between the heads or entirely external or internal to both heads of the external pterygoid muscle.

The **internal carotid artery** is rarely absent. Occasionally it springs from the arch of the aorta, and in its course through the neck it may vary somewhat in length and in tortuosity. One or more of the branches usually derived from the external carotid artery may arise from it, and it sometimes gives off a large meningeal branch to the posterior fossa of the skull. Its posterior communicating branch may replace the posterior cerebral artery; on the other hand, the upper part of the internal carotid may be absent, and the posterior communicating artery may become the middle cerebral artery. The anterior cerebral branch of the internal carotid may be absent, or rather it may arise from the corresponding artery of the opposite side; or there may be three anterior cerebral arteries, the third arising from the anterior communicating artery which connects the two anterior cerebrals together. The ophthalmic artery, as it traverses the orbit, may pass either over or under the optic nerve. It is occasionally replaced by a branch of the middle meningeal artery.

The **vertebral artery** may have a double origin—one from the subclavian, and one from the inferior thyroid artery or from the aorta.

The right vertebral may arise from the common carotid or from the arch of the aorta. Occasionally it springs from the descending aorta, an arrangement associated with the persistence of the dorsal roots of the fourth and fifth right arches.

The left vertebral artery not infrequently springs from the arch of the aorta, arising between the left common carotid and left subclavian arteries; this is evidently due to the absorption of the stem of the seventh segmental artery into the aortic arch. Very exceptionally the left vertebral is a branch of an intercostal artery.

In its course upwards either vertebral artery may enter the vertebrarterial foramen of any of the lower six cervical vertebra.

The cases in which it does not enter one of the lowest of these are apparently associated with its formation in part from the precostal instead of from the postcostal anastomosing channels.

The artery may enter the spinal canal with the second instead of with the first cervical nerve, or, after leaving the foramen in the transverse process of the third vertebra, it may divide into two branches, one of which accompanies the second and the other the first cervical nerve; the two branches unite together again in the spinal canal to form a single trunk.

Sometimes, though rarely, it gives off superior intercostal and inferior thyroid branches. The upper end of one of the vertebrals is sometimes very small, or it may be entirely wanting; in the latter case the basilar artery is formed by the direct continuation of the opposite vertebral.

The **basilar artery** may be double in part or the whole of its extent, or its cavity may be divided by a more or less complete septum. It may terminate in one instead of two posterior cerebral arteries, the missing vessel being supplied by the enlargement of the posterior communicating branch of the internal carotid.

The Arteries of the Upper Limb.

Subclavian Arteries.—The variations, so far as regards the origins of the subclavian arteries, have already been mentioned (p. 897). Other interesting modifications are met with in respect of its position and branches.

The subclavian artery may rise as high as one or even one-and-a-half inches above the clavicle, though as a rule it does not reach higher than three-quarters of an inch above that bone. On the other hand, it may not rise even to the level of the upper border of the clavicle. These differences appear to be associated with the descent of the clavicle and sternum, which occurs as age increases.

The artery may pass in front of or through the scalenus anticus instead of behind it, or the vein may accompany it behind the muscle.

The branches of the subclavian artery may be modified with reference to their points of origin ; thus those of the first part may be further in or out than usual, the suprascapular or some other branch of the thyroid axis may arise separately from the third part of the artery, and not uncommonly the posterior scapular artery is a branch of this part. The abnormalities of the vertebral branch have already been described ; those of the thyroid axis and its branches are numerous but not important.

The **internal mammary artery,** usually a branch of the first part of the subclavian, is very variable as regards its origin. It may arise from the second or third parts, or from the thyroid axis, or it may spring from the aorta, or from the innominate or axillary arteries. All these variations are due to obliteration of the normal origin and the opening up of anastomoses. The internal mammary artery sometimes descends in front of the cartilages of one or more of the lower true ribs, and occasionally it gives off a large lateral branch (a. mammaria lateralis) which descends on the inner side of the chest wall nearly in the mid-axillary line, a point of importance in paracentesis.

A few cases have also been noticed in which a bronchial artery has arisen from the internal mammary.

The **superior intercostal branch** of the subclavian may be absent. In any case its deep cervical branch may rise directly from the subclavian trunk. The superior intercostal is sometimes formed from a postcostal instead of a precostal primitive channel, and in this case it passes between the necks of the ribs and the transverse processes of the vertebræ instead of, as usual, in front of the necks of the ribs.

The **axillary artery** does not vary much as regards its origin or course. Its relations may be modified by the existence of a muscular or tendinous "axillary arch," which, passing from the latissimus dorsi to the pectoralis major, crosses the lower part of the artery superficially ; and a further interesting modification is associated with an anomalous arrangement of its branches. Occasionally the sub-scapular, circumflex, and superior and inferior profunda arteries arise from the axillary by a common stem. In these cases the chief branches of the brachial plexus are grouped round the common stem instead of round the main trunk, and it is suggested that the common stem in question was originally the trunk artery of the upper limb, the lower part of which has been obliterated, the circulation being carried on by a vas aberrans which anastomoses below either with the brachial artery or with one of the arteries of the forearm. It is also said that a rudiment of this artery exists in a muscular branch which passes between the heads of the median nerve.

Sometimes the axillary artery divides into the radial and ulnar arteries, and more rarely the interosseous artery may spring from it.

Obviously when the radial and ulnar arteries are formed by the division of the axillary, there is no brachial artery ; its place is taken by the two abnormal vessels which, as a rule, are separated by the median nerve as they run through the upper arm.; the radial is usually more superficial than the ulnar, and crosses outwards in front of it at the bend of the elbow.

The **brachial artery** is rarely prolonged beyond its usual point of bifurcation, not uncommonly, however, it bifurcates at a higher level. Of the two terminal branches of the brachial, one may divide into radial and interosseous, the other forming the ulnar ; or one may divide into radial and ulnar, whilst the other is the interosseous artery. Occasionally the brachial artery terminates by dividing into three branches—viz. the radial, the ulnar, and the interosseous. In any case, the branch which gives origin to or becomes the interosseous was in all probability the original trunk.

Division of the brachial artery at a higher level than usual occurs most commonly in the upper third of the arm, and least commonly in the lower third ; the resulting trunks are often united near the bend of the elbow by a more or less oblique anastomosis.

In cases of high division of the brachial artery the radial branch may pierce the deep fascia of the arm near the bend of the elbow, and descend in the forearm immediately beneath the skin ; in other cases the radial runs deeper, and passes behind the tendon of the biceps. The ulnar branch sometimes runs, on the internal intermuscular septum, towards the inner condyle, and then outwards towards the middle of the bend of the elbow under a band of fascia, from which the upper fibres of the pronator teres arise, or round the supracondylar process of the humerus if it is present. More commonly the ulnar branch descends towards the inner condyle, and crosses superficial to the flexor muscles or beneath the palmaris longus ; and in a few cases it is subcutaneous. Very occasionally the ulnar artery accompanies the ulnar nerve behind the inner condyle ; in these cases it has obviously been formed by enlargement of the ordinary inferior profunda and posterior ulnar recurrent arteries.

Instead of following its usual course along the brachialis anticus, the brachial artery may accompany the median nerve behind a supracondylar or epicondylic process, or ligament, as in many carnivores; it may pass in front of the median nerve instead of behind it. It may give off a "vas aberrans" or a median artery, and any of its ordinary branches may be absent.

The vas aberrans given off from the brachial artery usually ends in the radial artery, sometimes in the radial recurrent, and rarely in the ulnar artery.

The **ulnar artery** may be absent, being replaced by the "comes nervi mediani" or the interosseous artery, and it may terminate in the deep instead of in the superficial palmar arch. It rarely rises at a lower level than usual, and when it rises at a higher level it most commonly passes superficial to the muscles which spring from the internal epicondyle. Moreover, in these cases it frequently has no interosseous branch, the latter vessel springing from the radial artery, and in all probability variations of this description are produced by the ulnar artery taking origin from the main trunk, which is represented by the radio-interosseous vessel, at a higher level than usual. Even when it commences in the usual way the ulnar artery may pass superficial to the muscles from the internal epicondyle, and in these cases its interosseous and recurrent branches spring from the radial artery.

The anterior and posterior interosseous arteries may arise separately from the ulnar instead of by a common interosseous trunk. The recurrent branches of the ulnar may spring from the interosseous, and the interosseous itself may be a branch of the radial.

The small median artery, the companion artery of the median nerve, usually a branch of the anterior interosseous, may spring from the axillary, brachial, or ulnar arteries; it may be much larger than usual, and terminate either by breaking up into digital branches, or by joining one or more digital branches of the superficial palmar arch or the palmar arch itself.

The **radial artery** may be absent, its place being taken by branches of the ulnar or interosseous arteries; it may arise from the axillary, or, higher than usual, from the brachial. It may terminate in muscular branches in the front of the forearm, or in the superficialis volæ, or in carpal branches; the lower portion of the artery, in these cases, is usually replaced by branches of the ulnar or interosseous arteries. Occasionally the radial divides some distance above the wrist into two terminal branches, one of which gives off the carpal branches, and becomes the superficialis volæ, whilst the other crosses superficial to the extensor tendons and passes to the back of the wrist.

The radial artery may run a superficial course, or, and especially when it commences at a lower level than usual, it may pass beneath the pronator radii teres and the radial origin of the flexor sublimis digitorum. In some cases it passes to the back of the wrist across the supinator longus, and in others it lies upon, instead of beneath, the extensor tendons of the thumb.

Its branches may be diminished or increased in number. The radial recurrent may spring from the brachial or ulnar arteries, or may be represented by several branches from the upper part of the radial. The dorsalis indicis may be large, and may replace the princeps pollicis and the radialis indicis. On the contrary, the dorsal carpal artery and dorsal digital branches of the radial may be small, or the former may be replaced by branches of the interosseous arteries, and the latter by the superior perforating branches of the deep palmar arch.

The **princeps pollicis** and **radialis indicis** arteries may be absent, their places being taken either by branches of the superficial palmar arch or by the dorsalis indicis artery

The **superficial palmar arch** is sometimes absent; its branches are then given off from the deep arch. Conversely, it may be larger than normal, and it may be completed on the ulnar side by the radialis indicis, the princeps pollicis, or the comes nervi mediani arteries.

The **deep palmar arch** is much more rarely absent than the superficial arch. When absent its branches are supplied by the superficial arch, the superior perforating arteries, or the palmar carpal arch.

The Iliac Arteries and their Branches.

The **common iliac artery** may be longer or shorter than usual, a modification which is largely though not altogether determined by the point at which the bifurcation of the aorta takes place. If exceptionally long, it is usually tortuous. In rare cases in man the artery is absent. It occasionally gives off the middle or a lateral sacral artery, and ilio-lumbar, spermatic, or accessory renal branches may arise from it.

The **internal iliac artery** varies as regards length. It is usually longer, and rises at a higher level when the common iliac is short. In rare cases it has been found to arise from the aorta without the intervention of a common iliac. Frequently it does not, even in appearance, end in anterior and posterior divisions, but obviously forms a single trunk, as in the fœtus, from which the several branches are given off.

The visceral branches vary much in number and size, and the middle hæmorrhoidal may not be present, its place being taken by branches from the vesical arteries. A renal branch sometimes arises from the internal iliac.

The ilio-lumbar branch may rise from the common instead of from the internal iliac; the gluteal and sciatic may rise by a common stem, or the gluteal may be absent, and its place taken by a branch from the femoral artery; the sciatic artery may, as in the fœtus, constitute the main artery of the hind limb, and run down to become continuous with the popliteal artery. Probably the "comes nervi ischiadici" represents the original continuity of these two vessels. Occasionally the lateral sacral arteries do not arise from the internal iliac trunks.

In some few instances the **obturator artery** arises from the deep epigastric artery instead of from the internal iliac. The condition is apparently due to obliteration of the usual origin of

the obturator artery and to the subsequent enlargement of the anastomosing pubic branches of the obturator and deep epigastric arteries. The course of the abnormal obturator artery is of importance. From its origin it descends into the pelvis on the inner side of the external iliac vein, and in the majority of cases on the outer side of the crural ring, but in three-tenths of the cases, and more frequently in males than in females, it descends on the inner side of the ring.

The obturator artery sometimes gives off an accessory pudic branch which passes along the side of the prostate, pierces the triangular ligament, and terminates by dividing into the artery of the corpus cavernosum and the dorsal artery of the penis. When this occurs the pudic artery is small, and it terminates in the artery to the bulb. Occasionally the accessory pudic arises from the pudic artery in the pelvis, or from one of the vesical arteries.

The **external iliac artery** may be much smaller than usual, especially if the sciatic artery persists as the main vessel of the lower limb. It may give off two deep circumflex iliac branches, a dorsal artery of the penis, an internal circumflex artery of the thigh, or a vas aberrans, and its deep circumflex iliac and deep epigastric branches may arise at higher or lower levels than usual.

The Arteries of the Lower Limb.

The **femoral artery** is small, and ends in the profunda and circumflex branches, when the sciatic artery forms the principal vessel of the lower limb. The profunda branch, which usually rises from the outer side of the femoral trunk, about one-and-a-half inches below Poupart's ligament, may commence at a higher or a lower level, and from the back or the inner side of the femoral trunk. Absence of the profunda has been noted, and in these cases the branches usually given off by it spring directly from the femoral artery.

The femoral artery may be double for a portion of its extent, or it may be joined by a vas aberrans given off from the external iliac artery. In addition to its ordinary branches, it may furnish one or both of the circumflex arteries of the thigh, and sometimes it gives off, near the origin of the profunda, a great saphenous artery, such as exists normally in many mammals. This vessel descends through Scarpa's triangle and Hunter's canal, and accompanies the internal saphenous nerve to the inner side of the foot.

The deep circumflex iliac, the obturator, and the deep epigastric arteries are occasionally given off from the femoral.

The **popliteal artery** may exceptionally form the direct continuation of the sciatic artery. It sometimes divides at a higher or lower level than usual, and the division may be into either two or three branches; if three terminal branches are present, they are the anterior and posterior tibial and the peroneal arteries, and if only two, either the anterior and posterior tibial, or the anterior tibial and the peroneal arteries.

Occasionally the artery is double for a short portion of its course, and it has been found to cross first behind the inner head of the gastrocnemius to the inner side of the knee, and then in front of the inner head of the gastrocnemius to regain the popliteal space. The number of its branches may be reduced, or they may be increased by the addition of a vas aberrans which connects it with the posterior tibial artery. Its superficial sural branch may enlarge to form a well-marked small saphenous artery.

The **posterior tibial artery** may be small or altogether absent, its place being taken by branches of the peroneal artery; again, it may be longer or shorter than usual, in conformity with the higher or lower division of the popliteal trunk. The peroneal artery is large if either the anterior or posterior tibial arteries are small. The anterior terminal branch of the peroneal is almost invariably large when the anterior tibial artery is small; in some cases, indeed, it replaces the whole of the dorsalis pedis continuation of the latter vessel; in others, however, only the tarsal and metatarsal branches are so replaced. The peroneal sometimes arises from a stem common to it and the anterior tibial artery.

The **anterior tibial artery** may be absent, its place being taken by branches of the posterior tibial and peroneal arteries. It is longer than normal when the popliteal artery divides at a higher level than usual, and in these cases it may pass either behind or in front of the popliteus muscle. Occasionally the anterior tibial artery and its dorsalis pedis continuation are larger than normal, and the terminal part of the dorsalis pedis takes the place, more or less completely, of the external plantar artery.

The **internal plantar artery** is sometimes very small, and it may be absent; its place is taken by branches of the dorsalis pedis or external plantar arteries. The **external plantar artery** also may be small or absent, the plantar arch being formed entirely by the dorsalis pedis.

ABNORMALITIES OF VEINS.

Abnormalities or variations of veins are as frequently met with as those of arteries, and they are due to similar causes.

The Superior Vena Cava.

The **superior vena cava** may develop on the left side instead of the right. This peculiarity is due to the persistence of the left duct of Cuvier instead of that on the right side, and it is associated with absence of the coronary sinus, which is replaced by the lower part of the left superior vena cava. An exceptional case is recorded in which the opening of the coronary sinus

into the heart was obliterated, and the cardiac veins terminated in a trunk which passed upwards to the left innominate vein. This trunk was obviously formed by enlargement of the left duct of Cuvier and the lower part of the left primitive jugular vein. Not very uncommonly, as the result of the persistence of both ducts of Cuvier, there are two superior venæ cavæ, the transverse anastomosis which usually forms the left innominate vein being small or entirely absent. In these cases the left innominate vein descends in the left part of the superior mediastinum, crosses the aortic arch, is joined by the left superior intercostal vein, and becomes the left superior vena cava; this latter vessel descends in front of the root of the left lung, and terminates in the lower and back part of the right auricle. It receives the great cardiac vein, and, turning to the back of the heart, replaces the coronary sinus. This arrangement is normal in many mammals. Occasionally in man the left superior vena cava terminates in the left auricle, and the coronary sinus, which represents a part of the sinus venosus, has been seen to have a similar ending; both these abnormal endings must be the result of malposition of the interauricular septum.

The vena azygos major may be formed on the left side; it then arches over the root of the left lung, and terminates in the left end of the coronary sinus. This is the normal arrangement in some mammals, and it is due to the persistence of the left cardinal vein and the left duct of Cuvier.

The **azygos veins** may be reduced or increased in number. In the former case there may be only one azygos vein which receives the intercostal veins of both sides, or there may be two azygos veins, a right and a left, the left usually being divided into upper and lower sections which are connected by a smaller intermediate portion, and united to the right vein by one or more transverse anastomoses, or it may terminate by joining either the left innominate vein or the left superior vena cava. The small intermediate section on the left side may form a separate vessel, and then the number of the azygos veins is increased to four, each of the three left veins terminating in the right vein. When there is only one azygos vein the portion of the left cardinal vein, from which, usually, the vertical portions of the left azygos veins are formed, has disappeared, and the left intercostal veins open into the right azygos vein by separate transverse anastomoses, as in the case of the left lumbar veins and the inferior vena cava. On the other hand, when there is only one left azygos vein the intermediate sections of the thoracic part of the left cardinal vein and one or more of the transverse anastomoses have persisted, whilst, when the left azygos terminates in the left innominate vein, the transverse anastomoses have disappeared, and the lower part of the left primitive jugular vein has remained patent.

Occasionally the vena azygos major takes the place of the upper part of the inferior vena cava, and the whole of the left cardinal vein is enlarged; in these cases the upper portion of the normal inferior vena cava is absent or exceptionally small.

The **internal jugular vein** is sometimes smaller or larger than normal. In either case compensatory changes in size occur in the lateral sinus and internal jugular vein of the opposite side, or in the external and anterior jugular veins of the same side.

The **external jugular vein** is sometimes absent, or it may be smaller than usual; in both cases either the anterior or internal jugular veins are enlarged. In some of the cases in which the external jugular vein is small it receives no communication from the temporo-maxillary vein, but is merely the continuation of the posterior auricular vein. On the other hand, it may be enlarged, and receive the whole of the temporo-maxillary vein.

The **anterior jugular vein** may be absent, or it may be unusually large, especially in the lower part of its extent, and after it has received an occasional tributary from the common facial vein.

The **temporo-maxillary vein** may terminate entirely in the common facial vein, or in the external or the internal jugular vein. It may be very small, and occasionally it is absent.

Variations of the **cranial blood sinuses** are not numerous. One lateral sinus may be absent or very small when, as a rule, that of the opposite side is enlarged. The inferior longitudinal, the occipital, or the spheno-parietal sinuses may be absent, and there may be an additional petro-squamous tributary to the lateral sinus. The petro-squamous sinus, when present, is the remains of that portion of the primitive lateral sinus which crossed the temporal bone, passed through the post-condyloid foramen and terminated in the primitive jugular vein. Very occasionally in the human adult it still pierces the skull behind the condyle of the jaw, and terminates in the temporo-maxillary vein, and this is the normal arrangement in some mammals.

The Veins of the Upper Extremity.

The **superficial veins** of the forearm are extremely variable; any of them may be absent, but most commonly it is the median or the radial vein which is wanting. The median cephalic and the cephalic veins may be small or absent, and on the other hand the cephalic vein may be larger than usual. Moreover the cephalic vein may end in the external jugular vein, its original termination; or it may be connected with the external jugular vein by an anastomosing channel which sometimes passes over the clavicle and sometimes through that bone.

The basilic vein is sometimes larger and sometimes smaller than usual, and it may pierce the fascia of the arm at a higher or at a lower level than is customary.

The **venæ comites** of the arteries of the upper extremity generally terminate at the lower border of the subscapularis, where they join the axillary vein, but they may end above or below the position of their usual termination.

The **subclavian vein** sometimes passes behind instead of in front of the scalenus anticus muscle, and it has been seen passing between the clavicle and the subclavius muscle.

The Inferior Vena Cava.

The lower part of the inferior vena cava is sometimes absent, in which case the common iliac veins ascend, one on the right and the other on the left of the aorta, to the level of the second lumbar vertebra, where the left common iliac vein receives the left renal vein, and then crosses in front of or behind the aorta to fuse with the right corresponding vein ; in these cases, therefore, the inferior vena cava commences at the level of the second lumbar vertebra, and it represents only the upper and last-formed part of the ordinary vessel ; the common iliac veins, each of which receives the lumbar veins of its own side, are exceptionally long, and they may or may not be united at the pelvic brim by a small transverse anastomosing channel.

Occasionally the inferior vena cava does not terminate in the right auricle, but is continuous with the vena azygos major, which is much enlarged, all the inferior caval blood being then carried to the superior vena cava. In these cases the hepatic veins open directly into the right auricle without communicating with the inferior vena cava.

The lower part of the inferior vena cava sometimes lies to the left instead of to the right of the aorta ; this condition is associated with a long right common iliac vein, which crosses obliquely from right to left to join the shorter left common iliac vein. After receiving the left renal vein the misplaced inferior vena cava crosses in front of the aorta, reaching the right side at the level of the second or first lumbar vertebra. In other cases, however, the left inferior vena cava continues upwards through the left crus of the diaphragm, usurping the place of a greater or smaller part of the left azygos vein ; having entered the thorax, it may cross to the opposite side and terminate in the vena azygos major, or it may continue upwards on the same side, and after arching over the root of the left lung, descend behind the left auricle, to terminate in the right auricle in the situation of the coronary sinus. In this group of cases also the hepatic veins open separately into the right auricle.

The tributaries of the inferior vena cava are also subject to variation. Additional renal, spermatic, ovarian, or suprarenal veins may be present. Two or three lumbar veins of one or both sides may unite into a common trunk which terminates in the inferior vena cava, and the hepatic veins may open separately, or after fusing into a common trunk, into the right auricle near the opening of the inferior vena cava.

No explanation of the variations of the inferior vena cava and its tributaries is necessary, beyond the statement that they are due to persistence of portions of the cardinal veins which usually disappear, and to the persistence of transverse anastomoses and tributaries which usually atrophy, or to modifications of those which ordinarily take part in the formation of the inferior vena caval system.

The **left common iliac vein** is short and the right long when the inferior vena cava lies on the left side. The common iliac veins may be absent, the internal iliac veins uniting to form the commencement of the inferior vena cava, into which the external iliac veins open as lateral tributaries.

The Veins of the Lower Extremity.

The **long saphenous vein** is not subject to much variation, but the **short saphenous vein** may terminate by joining the long saphenous, or, after piercing the deep fascia in the lower part of the thigh, it may ascend and join the sciatic vein or one of the tributaries of the profunda vein.

The **venæ comites** are generally described as terminating in the lower extremity, at the lower part of the popliteal space, but they may ascend as far as Scarpa's triangle ; as a matter of fact, although as a rule there is only one large popliteal and one large femoral vein, one or more small additional veins usually accompany the popliteal and femoral arteries.

In a few cases the popliteal vein does not pierce the lower part of the adductor magnus, but ascends behind that muscle and becomes continuous with the profunda vein, the femoral artery being unaccompanied by any large vein during its passage through Hunter's canal.

ABNORMALITIES OF THE LYMPHATICS.

Variations of the glands and smaller vessels of the lymphatic system are so common that they can hardly be regarded as abnormalities ; variations of the larger vessels, however, are comparatively rare. This is especially the case with respect to the two terminal trunks, the thoracic duct and the right lymphatic duct, the abnormalities of which are interesting and important.

When the arch of the aorta is on the right instead of on the left side, the thoracic duct usually terminates in the right innominate vein, in which case it receives the tributaries which usually open into the right lymphatic duct, whilst the corresponding area on the left side is drained by lymphatics terminating in a left lymphatic duct which opens into the commencement of the left innominate vein. A similar arrangement of the terminal lymphatic trunks sometimes occurs even when the arch of the aorta is in its normal position on the left side. In either case the thoracic duct may commence in the usual way, and after reaching the level of the fifth dorsal vertebra continue upwards on the right side, instead of crossing to the left side, of the vertebral column ; more rarely it commences on the left side and crosses over to the right at a higher level.

In one case in which the thoracic duct opened into the right innominate vein, instead of the left, no trace of a lymphatic duct was discovered on the left side.

Occasionally the thoracic duct commences and terminates in the usual manner, but crosses the vertebral column immediately after its origin and ascends on the left side.

Not uncommonly there is no distinct receptaculum chyli, in which case the terminal lymphatic vessels of the abdomen merely unite to form a larger vessel which does not present any obvious dilatation, and from which the thoracic duct is continued. The terminal lymphatic trunk may open into the internal jugular vein previous to its junction with the subclavian, instead of into the commencement of the innominate vein.

Occasionally the thoracic duct is double, either on the whole or in part of its extent, and sometimes it breaks up into a plexus of vessels which may reunite into a single trunk in the upper part of the thorax. Both the thoracic duct and the right lymphatic duct may before terminating divide into branches which, though sometimes reuniting on each side into a single trunk, not infrequently open separately into the great veins at the root of the neck.

As a rule the thoracic duct joins the commencement of the left innominate vein, but it may end in the internal jugular, vertebral, or subclavian veins of the left side; whilst very rarely, it opens into the vena azygos major.

THE RESPIRATORY SYSTEM.

THE ORGANS OF RESPIRATION AND VOICE.

By D. J. Cunningham.

The organs of respiration are the larynx and trachea, which together constitute a wide median air-passage; the two bronchi or branches into which the lower end of the trachea divides; and the two lungs to which the bronchi conduct the air. In connexion with the lungs we have likewise to consider the pleural membranes—two serous sacs which line the portions of the thoracic cavity which contain the lungs, and at the same time give a thin coating to these organs.

The larynx opens above into the lower part of the pharynx, and the air which passes in and out from the air-passages likewise traverses the pharynx, the nasal fossæ, and also the buccal cavity if the mouth is open. This connexion between the digestive and respiratory systems is explained by the fact that the respiratory apparatus is secondarily developed as an outgrowth from the front aspect of the primitive fore-gut of the embryo. In most mammals the upper aperture of the larynx opens into the part of the pharynx which lies behind the nasal chambers. In man, however, the upper opening of the larynx is placed lower down, below the communication between the mouth and pharynx, and both nasal and buccal breathing may be carried on with very nearly equal ease.

THE LARYNX OR ORGAN OF VOICE.

The larynx is the upper part of the air-passage, specially modified for the production of the voice. Above, it opens into the pharynx, whilst below, its cavity becomes continuous with the lumen of the trachea or windpipe.

Position and Relations of the Larynx.—In the natural position of the neck, and whilst the organ is at rest, the larynx is placed in front of the bodies of the fourth, fifth, and sixth cervical vertebræ. Its highest point, represented by the tip of the epiglottis, reaches as high as the lower border of the body of the third cervical vertebra, whilst its lower limit usually corresponds to the lower border of the body of the sixth cervical vertebra. From the vertebral column the larynx is separated, not only by the prevertebral muscles and prevertebral layer of cervical fascia, but also by the posterior wall of the pharynx—indeed, the posterior surface of the larynx forms the lower part of the anterior wall of the pharynx, and is covered by the lining mucous membrane of that section of the alimentary canal.

The larynx lies below the hyoid bone and the tongue, and in the interval between the great vessels of the neck. It forms a more or less marked projection on the front of the neck, and in the median line it approaches very close to the surface, being merely covered by skin and the two layers of fascia. Laterally it is more deeply placed. Thus it is overlapped by the sterno-mastoid muscle, covered by the two strata of thin ribbon-like muscles which are attached to the thyroid cartilage and the hyoid bone, and hidden to some extent by the upward prolongations of the lateral lobes of the thyroid body.

The position of the larynx is influenced by movements of the head and neck. Thus it is elevated when the head is thrown back, and depressed when the chin is carried down-

wards towards the chest. Again, if the finger is placed on the larynx during deglutition, it will be seen that the larynx moves to a very considerable extent. The pharyngeal muscles attached to it, and more especially the stylo-pharyngeal muscles, are chiefly responsible for bringing about these movements. During singing, changes in the position of the larynx may also be noted, a high note being accompanied by a slight elevation, and a low note by a slight depression of the organ.

The position of the larynx is not the same at all periods of development and growth. In the fœtus, shortly before birth, it lies much higher up in the neck. Thus its lower border corresponds to the lower border of the fourth cervical vertebra. Its permanent position is not reached until the period of puberty is attained (Symington). This descent of the larynx has been stated to be due to the rapid and striking growth of the facial part of the skull which lies above it (Symington). It is very doubtful, however, if the facial growth has any influence in this direction. In the anthropoid ape, in which the face forms a much greater part of the skull than in man, and in which, in the transition from the infantile to the adult condition, the facial growth is even more striking than in man, the larynx occupies a relatively higher position in the neck. In the early stages of growth all the thoracic viscera undergo a gradual subsidence. The larynx in its descent follows these. Indeed it cannot do otherwise, seeing that the bifurcation of the trachea between infancy and puberty moves downwards more than the depth of one thoracic vertebra.

General Construction of the Larynx.—The wall of the larynx is constructed upon a somewhat complicated plan. There is a frame-work composed of several cartilages. These are connected together at certain points by distinct joints and also by elastic membranes. Two elastic cords, which stretch in an antero-posterior direction from the front to the back wall of the larynx, form the ground-work of the true vocal cords. Numerous muscles are likewise present. These operate upon the cartilages of the larynx, and thereby not only bring about changes in the relative position of the true vocal cords, but also produce different degrees of tension of these cords. The cavity of the larynx is lined with mucous membrane, under which, in certain localities, are collected masses of mucous glands.

CARTILAGES OF THE LARYNX.

There are three single cartilages and three pairs of cartilages entering into the construction of the laryngeal wall. They are named as follows:—

Single cartilages	Thyroid. Cricoid. Epiglottis.	Paired cartilages	Arytenoid. Cornicula laryngis, or the cartilages of Santorini. Cuneiform cartilages.

Thyroid Cartilage (cartilago thyreoidea).—The thyroid cartilage, the largest of the laryngeal cartilages, is formed of two quadrilateral plates termed the **alæ**, which meet in front at an angle, and become fused along the mesial plane. Behind, the alæ diverge from each other, and enclose a wide angular space which is open behind. The *anterior borders* of the alæ are only fused in their lower parts. Above they are separated by a deep, narrow V-shaped median notch, called the **incisura thyroidea**. In the adult male the angle formed by the meeting of the anterior borders of the two alæ, especially in its upper part, is very projecting, and with the margins of the thyroid notch, which lies above, constitutes a marked subcutaneous prominence in the neck, which receives the name of the **pomum Adami**.

The angle which is formed by the meeting of the two alæ of the thyroid cartilage varies to some extent in different individuals of the same sex, and shows marked differences in the two sexes and at different periods of life. In the adult male the average angle is said to be 90°; in the adult female it is 120°; whilst in the infant the alæ meet in the form of a gentle curve convex to the front.

The *posterior border* of each ala of the thyroid cartilage is thick and rounded, and is prolonged beyond the superior and inferior borders in the form of two slender cylindrical processes, termed cornua. The **superior cornu** is longer than the inferior cornu. It is directed upwards, with a slight inclination inwards and backwards, and it ends in a rounded extremity, which is joined to the tip of the great cornu of

the hyoid bone by the lateral thyro-hyoid ligament. The **inferior cornu** is shorter and stouter than the superior cornu. As it proceeds downwards it curves slightly inwards, and upon the inner face of its extremity it shows a circular flat facet, by means of which it articulates with a similar facet on the lateral aspect of the cricoid cartilage. The *superior border* of the ala is for the most part slightly convex, and in front it dips suddenly down to become continuous with the margin of the thyroid notch. Posteriorly, where it joins the superior cornu, it exhibits a shallow notch or concavity. The *inferior border* is to all intents and purposes horizontal, but it is marked off by a projection, termed the **inferior tubercle**, into a short posterior part, which shows a shallow concavity in front of the inferior cornu, and a longer part which lies in front of the tubercle, which is also concave, but to a less degree. The *external surface* of the ala is divided into two unequal areas by an **oblique line** or ridge. This line begins above at the **superior tubercle**, a prominence situated immediately below the superior border, and a short distance in front of the root of the superior cornu. From this the oblique line proceeds downwards and forwards, to end inferiorly in the inferior tubercle on the lower border of the ala. The area which lies behind the oblique line is much smaller than that which lies in front.

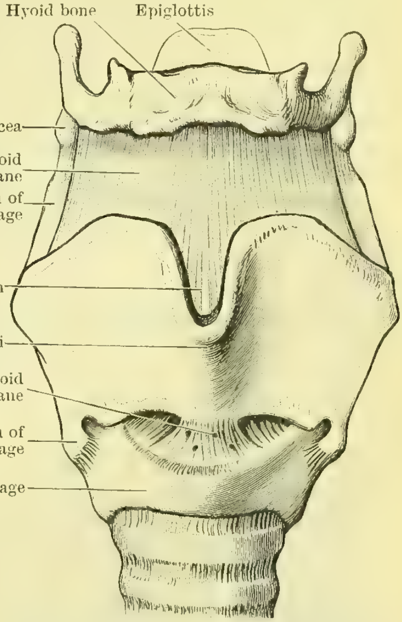


Fig. 612.—The Cartilages and Ligaments of the Larynx viewed from the Front.

It is covered by the inferior constrictor muscle of the pharynx. The larger anterior area is for the most part covered by the thyro-hyoid muscle. To the oblique line are attached the sterno-thyroid and thyro-hyoid muscles. The *inner surface* of the ala of the thyroid cartilage is smooth and slightly concave.

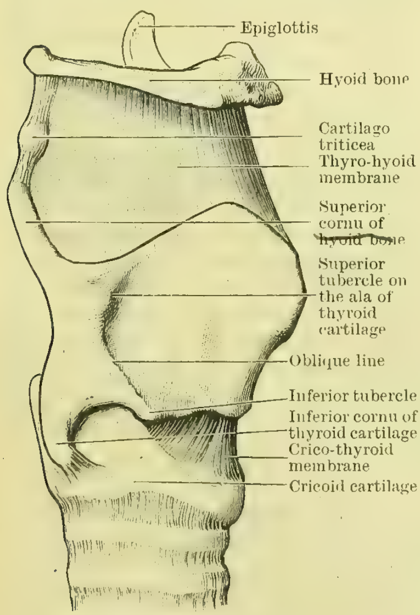


Fig. 613.—Profile View of the Cartilages and Ligaments of the Larynx.

Cricoid Cartilage (cartilago cricoidea).—The cricoid cartilage is shaped like a signet-ring. Behind, there is a broad, thick, and somewhat quadrilateral plate, termed the **posterior lamina**; whilst in front and laterally, the circumference of the ring is completed by a curved band, called the **anterior arch**. The lumen of the ring enclosed by these parts is circular below, but above, the ring is compressed laterally, so that the lumen becomes elliptical. The superior border of the **posterior lamina** presents a faintly-marked mesial notch. On either side of this there is an oval convex facet which looks more outwards than upwards, and which articulates with the base of the arytenoid cartilage. The posterior surface of the lamina is divided by an elevated median ridge into two depressed areas which give attachment to the posterior crico-arytenoid muscles. The front part of the **anterior arch** of the cricoid is in the form of a narrow band, but as it proceeds backwards towards the posterior lamina its superior border rises rapidly, and in consequence the arch becomes much

broader. The *inferior border* of the cricoid is nearly horizontal, although it frequently presents a median projection in front, and a lateral projection on either side. It is joined to the first ring of the trachea by an intervening elastic membrane. On the *outer surface* of the cricoid cartilage, at the place where the anterior arch joins the posterior lamina, a vertical ridge descends from the arytenoid articular facet. On this, a short distance from the lower border of the cartilage, a prominent circular articular facet is visible for articulation with the inferior cornu of the thyroid cartilage (Fig. 615, p. 913). The *inner surface* of the cricoid cartilage is smooth, and is lined by mucous membrane.

The narrow band-like part of the anterior arch of the cricoid cartilage lies below the lower border of the thyroid cartilage, whilst the posterior lamina is received into the interval between the posterior portions of the alæ of the thyroid cartilage.

Arytenoid Cartilages (cartilagines arytænoideæ).—The arytenoid cartilages are placed one on either side of the mesial plane, and rest upon the upper border of the posterior lamina of the cricoid cartilage, in the interval between the posterior portions of the alæ of the thyroid cartilage. They present a somewhat pyramidal form. The pointed **apex** or summit of each is directed upwards, and at the same time curves backwards and inwards. It supports the corniculum laryngis. Of the three surfaces, one looks directly inwards towards the corresponding surface of the opposite cartilage, from which it is separated by a narrow interval; another looks backwards; whilst the third is directed outwards and forwards. The *internal surface*, which is the smallest of the three, is triangular in outline. It is narrow, vertical, and even, and is clothed by the lining mucous membrane of the larynx. The *posterior surface* is smooth and concave from above downwards; it lodges and gives attachment to the arytenoideus transversus muscle. The *antero-external* surface is the most extensive of the three. Its middle part is marked by a deep depression in which is lodged a mass of mucous glands. Upon this surface of the arytenoid cartilage the powerful thyro-arytenoid muscle is inserted, whilst a small tubercle a short distance above the base gives attachment to the superior thyro-arytenoid ligament—the feeble supporting ligament of the false vocal cord. The three surfaces of the arytenoid cartilage are separated from each other by an anterior, a posterior, and an external border. The *external border* is the longest, and it pursues, as it is traced from the apex to the base, a sinuous course. Reaching the base of the cartilage, it is prolonged outwards and backwards in the form of a stout prominent angle or process, termed the **processus muscularis**. Into the front of this process is inserted the crico-arytenoideus lateralis muscle; whilst into its posterior aspect the crico-arytenoideus posticus muscle is inserted. A small nodule of yellow elastic cartilage, called the **sesamoid cartilage**, is frequently found on the external border of the arytenoid cartilage, where it is held in position by the investing perichondrium. The *anterior border* of the arytenoid is vertical, and at the base of the cartilage is prolonged horizontally forwards into a sharp-pointed process called the **processus**

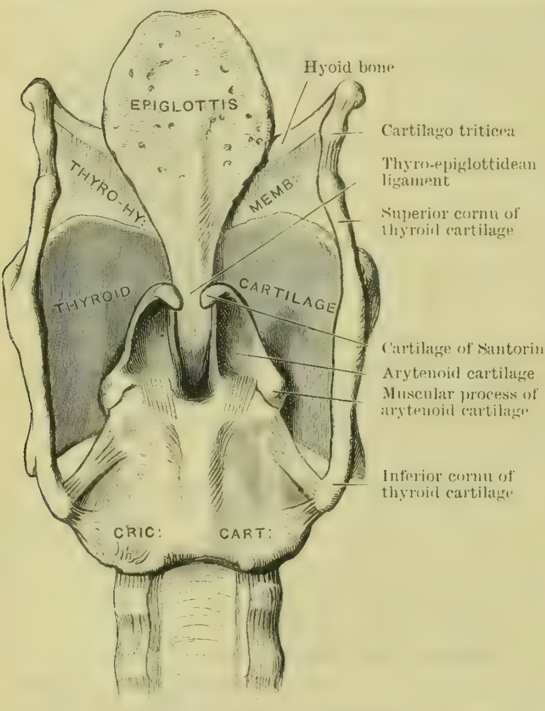


FIG. 614.—CARTILAGES AND LIGAMENTS OF LARYNX, as seen from behind.

vocalis. It receives this name because it gives attachment to the inferior thyro-arytenoid ligament or supporting band of the true vocal cord. The **base** of the arytenoid cartilage presents on its under surface, and more particularly on the under surface of the processus muscularis, an elongated concave facet for articulation with the upper border of the posterior lamina of the cricoid cartilage.

Cartilages of Santorini (cartilagines corniculatæ).—The cartilages of Santorini, or the cornicula laryngis, are two minute conical nodules of yellow elastic cartilage which surmount the apices of the arytenoids, and prolong the upper curved ends of these cartilages in a backward and inward direction. Each cartilage of Santorini is enclosed within the posterior part of the corresponding aryteno-epiglottidean fold of mucous membrane.

Cuneiform Cartilages (cartilagines cuneiformes).—The cuneiform cartilages are not invariably present. They are two minute rod-shaped pieces of yellow elastic cartilage, each of which occupies a place in the corresponding aryteno-epiglottidean fold of mucous membrane immediately in front of the arytenoid cartilage and the cartilage of Santorini. On the superficial surface of each a collection of mucous glands is present, and this tends to make the cartilage stand out in relief under the mucous membrane.

Epiglottidean Cartilage (cartilago epiglottica).—The epiglottis is supported by a thin leaf-like lamina of yellow fibro-cartilage which is placed behind the root of the tongue and the body of the hyoid bone, and in front of the superior aperture of the larynx. When divested of the mucous membrane, which covers it behind and also to some extent in front, the epiglottidean cartilage is seen to present the outline of a bicycle-saddle, and to be indented by pits and pierced by numerous perforations. In the former, glands are lodged, whilst through the latter, blood-vessels and in some cases nerves pass. The broad end of the cartilage is directed upwards, and is free. Its margins are, to a large extent, enclosed within the aryteno-epiglottidean folds of mucous membrane. The anterior surface is only free in its upper part. This part is covered with mucous membrane, and looks towards the base of the tongue. The posterior surface is covered throughout its whole extent by the lining mucous membrane of the laryngeal cavity. The lower pointed extremity of the cartilage is carried downwards in the form of a strong fibrous band, termed the thyro-epiglottidean ligament.

Ossification of the Cartilages of the Larynx. — The thyroid and cricoid cartilages and the greater part of the arytenoid cartilages are composed of the hyaline variety of cartilage. The apical parts, and also the vocal processes of the arytenoid cartilages, the cartilages of Santorini, the cuneiform cartilages, and the epiglottis, are formed of yellow fibro-cartilage, and at no period of life do they exhibit any tendency towards the ossific change. The thyroid, cricoid, and basal portions of the arytenoids, as life advances, become more or less completely transformed into bone. In males over twenty years of age, and in females over twenty-two years of age, the process will usually be found to have begun (Chievitz). It is impossible, however, by an examination of the laryngeal cartilages, to form an estimate of the age of the individual, although in old age it is usual to find the thyroid, cricoid, and the hyaline part of the arytenoid completely ossified. It would appear that the process is somewhat slower in the female than in the male. The thyroid is the first to show the change; then, but almost at the same time, the cricoid, and lastly, a few years later, the arytenoid.

JOINTS, LIGAMENTS, AND MEMBRANES OF THE LARYNX.

Crico-thyroid Joints (articulationes cricothyreoideæ).—These are diarthrodial joints, and are formed by the apposition of the circular facets on the tips of the inferior cornua of the thyroid cartilage with the elevated circular facets on the sides of the cricoid cartilage. A capsular ligament is thrown around each articulation, and this is lined by synovial membrane. On the posterior aspect of the joint a strengthening band is present in the capsule. The movements which take place at the crico-thyroid joints are of a twofold character, viz. gliding and rotatory. In the first case the thyroid facets glide upon the cricoid surfaces in different directions. The rotatory movement is one in which the thyroid cartilage rotates to a slight extent around a transverse axis which passes through the centre of the two joints.

Crico-arytenoid Joints (articulationes cricoarytænoideæ).—These also are diarthrodial articulations. In each case there is a joint cavity surrounded by a capsular ligament, which is lined by a synovial membrane. The cricoid articular surface is convex, whilst that of the arytenoid is concave; both are elongated or elliptical in form, and they are applied to each other, so that the long axis of the one intersects or crosses that of the other. In no position of the joint do the two surfaces accurately coincide—a portion of the cricoid facet is always left uncovered. The capsule of the joint is strengthened behind by a band which is inserted into the inner and back part of the base of the arytenoid cartilage, and plays a somewhat important part in the mechanism of the joint: it arrests effectually forward movement of the arytenoid cartilage.

The movements which take place at the crico-arytenoid joint are of a twofold kind, viz. gliding and rotatory. The ordinary position of the arytenoid during easy, quiet breathing is one in which it rests upon the outer part of the cricoid facet. By a gliding movement it can ascend upon the cricoid facet, and advance towards the median plane and its fellow of the opposite side. The gliding movements, therefore, are of such a character that the two arytenoid cartilages approach or retreat from each other and the mesial plane. In the rotatory movement the arytenoid cartilage revolves around a vertical axis. By this movement the vocal process is swung outwards or inwards, so as to open or close the rima glottidis.

The **joint between the arytenoid and the cartilage of Santorini** may either partake of the nature of an amphiarthrosis or of a diarthrosis. The tips of the two cornicula laryngis can generally be made out to be connected to the upper border of the posterior lamina of the cricoid cartilage by a delicate Y-shaped ligament termed the **ligamentum jugale.**

Thyro-hyoid Membrane (membrana hyothyreoidea).—This is a broad membranous and somewhat elastic sheet which occupies the interval between the hyoid bone and the thyroid cartilage. It is not equally strong throughout. It presents a central thick portion and a cord-like right and left margin, whilst in the intervals between these it is thin and weak. The central thickened part (ligamentum thyro-hyoideum medium) is largely composed of elastic fibres. Below, it is attached to the margins of the thyroid notch, whilst above, it is fixed to the posterior aspect of the upper margin of the body of the hyoid bone. The upper part, therefore, of its anterior surface is placed behind the posterior hollowed-out surface of the body of the hyoid bone; a synovial bursa of variable extent is placed between them, and in certain movements of the head and larynx the upper border of the thyroid cartilage slips upwards behind the hyoid bone. On either side of the strong central part, the thyro-hyoid membrane is thin and loose. It is attached below to the upper border of the thyroid cartilage, and above to the posterior aspect of the great cornu of the hyoid bone. It is pierced by the internal laryngeal nerve and the superior laryngeal vessels. The posterior border of the thyro-hyoid membrane on each side is thickened, round, and cord-like, and is chiefly composed of elastic fibres. It is termed the **ligamentum thyro-hyoideum laterale**, and extends from the tip of the great cornu of the hyoid bone to the extremity of the superior cornu of the thyroid cartilage. In this ligament there is usually developed a small oval cartilaginous or bony nodule which receives the name of the **cartilago triticea.** The deep surface of the lateral part of the thyro-hyoid membrane is covered by the pharyngeal mucous membrane. Behind its central part lies the epiglottis, but separated from it by a mass of adipose tissue (Fig. 618, p. 916).

Crico-thyroid Membrane (membrana cricothyreoidea).—This is a very important structure, which must be considered in three parts, viz. a central and two lateral, all of which are directly continuous with each other, and differ only in the nature of their superior connexions. The **central part** of the crico-thyroid membrane is strong, tense, and elastic. It is triangular in shape, and is attached by its broad base to the upper border of the anterior arch of cricoid cartilage, whilst above, it is fixed to the middle part of the lower border of the thyroid cartilage (Fig. 612, p. 909). It is pierced by minute apertures, and is crossed superficially by the crico-thyroid branch of the superior laryngeal artery. The central part of the crico-thyroid membrane, therefore, closes in front the interval between the cricoid and thyroid cartilages.

The **lateral part** on each side presents very different connexions. It is not attached to the lower border of the thyroid cartilage, but slopes upwards and inwards within the thyroid ala, and thus diminishes materially the transverse width of the lower subdivision of the laryngeal cavity. Its attachments are very definite. *Below*, it is fixed to the upper border of the cricoid cartilage, immediately subjacent to the lining mucous membrane of the larynx; *above*, it is directly continuous with the inferior thyro-arytenoid ligament or supporting band of the true vocal cord. This ligament, indeed, may be looked upon as constituting the upper thickened free border of the lateral part of the crico-thyroid membrane. *In front*, the lateral part of the crico-thyroid membrane is attached to the lower half of the inner surface of the ala of the thyroid cartilage, close to the angle, and *behind*, to the lower border of the processus vocalis of the arytenoid cartilage. In contact with the *outer surface* of the lateral part of the crico-thyroid membrane, and separating it from the thyroid ala, are the lateral crico-thyroid and the thyro-arytenoid muscles; the *inner surface* is clothed by the lining mucous membrane of the larynx.

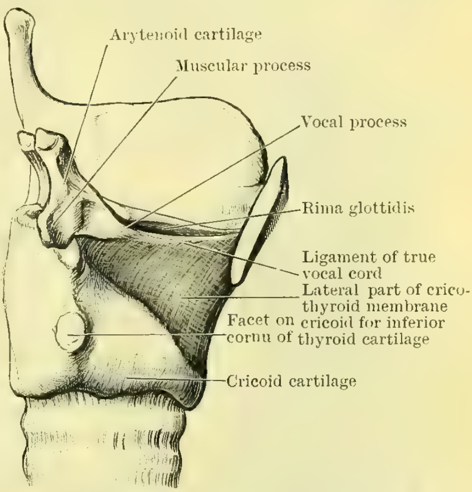


FIG. 615.—DISSECTION TO SHOW THE LATERAL PART OF THE CRICO-THYROID MEMBRANE. The right ala of the thyroid cartilage has been removed.

Inferior Thyro-arytenoid Ligament (ligamentum vocale).—This is formed in connexion with the upper border of the lateral part of the crico-thyroid membrane, and it constitutes the supporting ligament of the true vocal cord. It is attached *in front*, close to its fellow of the opposite side, to the middle of the angular depression between the two alæ of the thyroid cartilage. From this it stretches backwards, and becomes incorporated with the tip and upper border of the processus vocalis which projects forwards from the base of the arytenoid cartilage. The inferior thyro-arytenoid ligament is composed of yellow elastic fibres, and embedded in its anterior extremity there is frequently a minute nodule of elastic cartilage. Its inner border is sharp and free, and is clothed by mucous membrane, which in this position is very thin and tightly bound down to the ligament.

The **superior thyro-arytenoid ligament** (ligamentum ventriculare) supports the false vocal cord. It is weak and indefinite, but somewhat longer than the preceding ligament. In front it is attached to the angular depression between the two alæ of the thyroid cartilage, above the true vocal ligaments and close to the attachment of the thyro-epiglottidean ligament, and it extends backwards to be fixed to a tubercle on the antero-external surface of the arytenoid cartilage, a short distance above the processus vocalis. It is composed of connective tissue and elastic fibres which are continuous with the fibrous tissue in the aryteno-epiglottidean fold.

Epiglottidean Ligaments.—The epiglottis is bound by ligaments to the base of the tongue, to the hyoid bone, and to the thyroid cartilage. The **glosso-epiglottidean ligaments** are three in number, viz. a middle and two lateral. The **middle glosso-epiglottidean ligament** (plica glosso-epiglottica mediana) is a prominent mesial fold of mucous membrane which proceeds from the middle of the anterior free surface of the epiglottis to the base of the tongue. The **lateral glosso-epiglottidean ligaments** (plicæ glosso-epiglotticæ laterales) are similar mucous folds which proceed from the margins of the epiglottis to the side of the base of the tongue and to the pharyngeal wall. From the latter attachment they are sometimes called the pharyngo-epiglottic folds. Between the two layers of mucous membrane which form each of these three folds there is a certain amount of elastic tissue. By the glosso-epiglottidean folds the depression between the root of the tongue and the epiglottis is marked off into two fossæ termed the **valleculæ**.

The **hyo-epiglottidean ligament** (ligamentum hyoepiglotticum) is a short, broad

elastic band, somewhat broken up by adipose tissue, which connects the anterior face of the epiglottis to the upper border of the hyoid bone. The **thyro-epiglottidean ligament** (ligamentum thyreoepiglotticum) is strong and thick (Fig. 614, p. 910). Composed mainly of elastic tissue, it proceeds downwards from the lower pointed extremity of the epiglottis, and is attached to the angular depression between the two alæ of the thyroid cartilage below and behind the median notch.

A triangular interval is left between the anterior face of the epiglottis and the thyro-hyoid membrane. This is imperfectly closed above by the hyo-epiglottidean ligament, and contains a pad of soft fat (Fig. 618, p. 916).

INTERIOR OF THE LARYNX.

The cavity of the larynx is smaller than might be expected from an inspection of its exterior. On looking into its interior through the superior aperture it is seen to be subdivided into three portions by two elevated folds of mucous membrane which extend from before backwards, and project inwards from each side-wall of the cavity. The upper pair of folds are the **false vocal cords**; the lower, more definite pair, are the **true vocal cords.** The latter are the chief agents in the production of the voice, and the larynx is so constructed that changes in their relative position and in their degree of tension are brought about by the action of the muscles and the recoil of the elastic ligaments.

Superior Aperture of the Larynx (aditus laryngis).—This is a large obliquely-placed opening which slopes rapidly from above downwards and backwards. Somewhat triangular in outline, the basal part of the aperture, placed above and in front, is formed by the free border of the epiglottis. Behind, the opening rapidly narrows, and finally ends in the interval between the two arytenoid cartilages. The sides of the aperture are formed by two sharp and prominent folds of mucous membrane called the **aryteno-epiglottidean folds** (plicæ aryepiglotticæ), which stretch between the lateral margins of the epiglottis in front and the arytenoid cartilages behind.

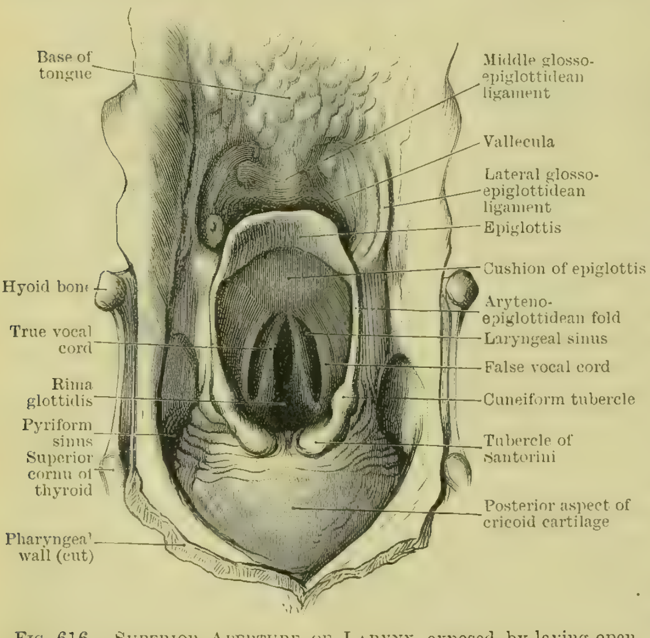


FIG. 616.—SUPERIOR APERTURE OF LARYNX, exposed by laying open the pharynx from behind.

The aryteno-epiglottidean folds enclose between the two layers of mucous membrane which compose them some connective tissue, muscular fibres belonging to the aryteno-epiglottidean muscles, and in their posterior parts the cuneiform cartilages and the cornicula laryngis which surmount the arytenoid cartilages. These small nodules of cartilage raise the hinder part of the aryteno-epiglottidean fold in the form of two rounded eminences, termed respectively the **cuneiform tubercle** (tuberculum cuneiforme) and the **tubercle of Santorini** (tuberculum corniculatum).

On either side of the posterior part of the laryngeal opening there is, in the pharynx, a small downwardly-directed recess which presents a wide entrance, but rapidly narrows towards the bottom. It is termed the **sinus pyriformis**, and it is important to the surgeon, because foreign bodies introduced into the pharynx are liable to be caught in this little pocket. On the inner side the sinus pyriformis is

bounded by the arytenoid cartilage and the aryteno-epiglottidean fold, whilst on the outer side it is limited by the inner surface of the ala of the thyroid cartilage, clothed by the pharyngeal mucous membrane.

Upper Subdivision of the Laryngeal Cavity (vestibulum laryngis).—The upper subdivision of the laryngeal cavity extends from the superior opening of the larynx down to the false vocal cords. In its lower part it exhibits a marked lateral compression. Its width, therefore, diminishes from above downwards, whilst, owing to the obliquity of the upper aperture of the larynx, its depth rapidly diminishes from before backwards. *In front* it is bounded by the posterior surface of the epiglottis, clothed by mucous membrane. This wall descends obliquely from above downwards and forwards, and becomes narrower as it approaches the anterior ends of the false vocal cords. The upper part of the posterior surface of the epiglottis is convex, owing to the manner in which the upper margin is curved forwards towards the tongue; below this there is a slight concavity, and still lower a marked bulging or convexity over the upper part of the thyro-epiglottidean ligament. This swelling is called the **cushion** or **tubercle of the epiglottis** (tuberculum epiglotticum), and it forms a conspicuous object in laryngoscopic examinations of the larynx. The *lateral wall* of the upper compartment or vestibule of the larynx is formed by the inner surface of the aryteno-epiglottidean fold. For the most part it is smooth and slightly concave, and it diminishes considerably in vertical depth as it passes backwards. In its posterior part the mucous membrane stands out in two elongated vertical elevations placed one behind the other (Fig. 618, p. 916). The anterior elevation is formed by the subjacent cuneiform cartilage with the mass of glands associated with it; the posterior elevation is produced by the anterior margin of the arytenoid cartilage and the cartilage of Santorini. A shallow groove (filtrum ventriculi of Merkel) descends between these rounded elevations, and terminates below by running into the interval between the false and true vocal cords. The anterior elevation comes to an end below in the posterior extremity of the false vocal cord; the arytenoid or posterior elevation, in its inferior part, bends round the hinder end of the ventricle of the larynx and becomes lost in the true vocal cord. The *posterior wall* of the laryngeal vestibule is narrow, and corresponds to the interval between the upper parts of the two arytenoid cartilages. Its width, to a large extent, depends on the position of these cartilages, and when they are placed near each other the mucous membrane which covers this wall is thrown into longitudinal folds.

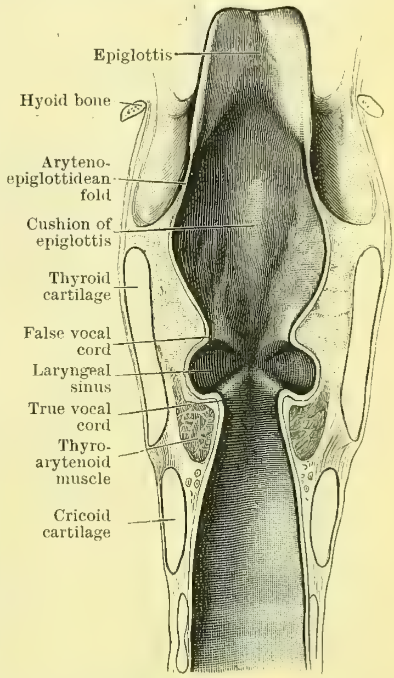


FIG. 617.—CORONAL SECTION THROUGH LARYNX, to show its three compartments.

Middle Subdivision of the Laryngeal Cavity.—The middle compartment of the larynx is much the smallest of the three. It is bounded above by the false vocal cords and below by the true vocal cords, whilst it communicates between these folds with the vestibule on the one hand and the inferior compartment of the larynx on the other.

The **false vocal cords** (plicæ ventriculares) are two prominent mucous folds which extend from before backwards on the side walls of the laryngeal cavity. In front they reach the angle between the two alæ of the thyroid cartilage, but behind they do not extend so far as the posterior wall of the larynx. They come to an end on each side at the lower end of the elongated swelling produced by cuneiform cartilage. The false vocal cord is soft and somewhat flaccid, and presents a free border which is slightly arched—the concavity looking downwards. Within the fold of mucous membrane which forms this cord are contained: (1) the feeble

superior thyro arytenoid ligament; (2) numerous glands which are chiefly aggregated in its middle part; and (3) a few muscle fibres.

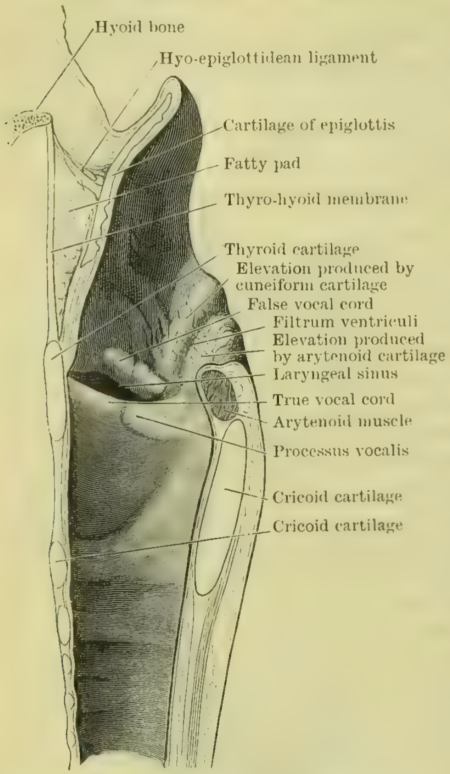


Fig. 618.—Mesial Section through Larynx, to show the outer wall of the right half.

The interval between the false vocal cords is sometimes termed the **false glottis** (glottis spuria), and is considerably wider than the interval between the true vocal cords, which is called the **true glottis** (glottis vera) or **rima glottidis**. It follows from this that when the cavity of the larynx is examined from above the four cords are distinctly visible, but when examined from below the true vocal cords alone can be seen.

The **true vocal cords** (plicæ vocales), placed below the false cords, extend from the angle between the alæ of the thyroid cartilage in front to the vocal processes of the arytenoid cartilages behind. The true vocal cord is sharp and prominent, and the mucous membrane which is stretched over it is very thin and firmly bound down to the subjacent ligament. In colour it is pale, almost pearly white, whilst posteriorly the point of the processus vocalis of the arytenoid, which stands out clearly in relief, presents a yellowish tinge. In cross-section the true vocal cord is prismatic in form, and its free border looks upwards as well as inwards.

The true vocal cords are the agents by means of which the voice is produced. The false vocal cords are of little importance in this respect; indeed, they can in great part be destroyed and no appreciable difference in the voice result.

Glottis vera (rima glottidis).—This name is applied to the elongated fissure by means of which the middle compartment of the larynx communicates with the lower compartment. It is placed somewhat below the middle of the laryngeal cavity, of which it constitutes the narrowest part. In front it corresponds to the interval between the true vocal cords; behind, it corresponds to the interval between the bases and vocal processes of the arytenoid cartilages. It is composed, therefore, of two distinct parts: (1) a narrow anterior portion, between the true vocal cords, involving more than half of its length, and called the **glottis vocalis** (pars intermembranacea); (2) a broader, shorter portion, between the arytenoid cartilages, and termed the **glottis respiratoria** (pars intercartilaginea). By changes in the position of the arytenoid cartilages the form of the rima glottidis undergoes constant alterations. In ordinary easy breathing it is somewhat lanceolate in outline. The glottis vocalis presents under these conditions the form of an elongated triangle with the base directed backwards, and corresponding to an imaginary line drawn between the

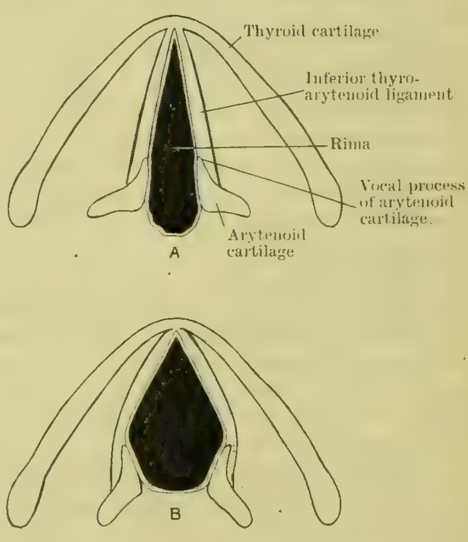


Fig. 619.—Diagram of Rima Glottidis.
A. During ordinary easy breathing. B. Widely open.

points of the vocal processes of the arytenoid cartilages, whilst the glottis respiratoria is somewhat quadrangular. When the glottis is opened widely the broadest part of the fissure is at the extremities of the vocal processes of the arytenoids, and here the side of the rima presents a marked angle. The two vocal cords, on the other hand, may be approximated to each other so closely, as in singing a high note, that the glottis vocalis is reduced to a linear chink.

The length of the rima glottidis differs very considerably in the two sexes, and upon this depends the different character of the voice in the male and female. According to Moura, the following are the average measurements in the quiescent condition of the rima :—

Male—Length of entire rima glottidis, 23 mm.	glottis vocalis, 15·5 mm. glottis respiratoria, 7·5 mm.
Female—Length of entire rima glottidis, 17 mm.	glottis vocalis, 11·5 mm. glottis respiratoria, 5·5 mm.

By stretching the vocal cords, however, the length of the rima glottidis in the male may be increased to 27·5 mm., and in the female to 20 mm.

The position of the rima glottidis may be indicated on the surface by marking a point on the middle line of the neck 8·5 mm. below the bottom of the thyroid notch in the male and 6·5 mm. in the female. This is the average position (Taguchi).

Laryngeal Sinus (ventriculus laryngis).—The side wall of the larynx, in the interval between the false and the true vocal cords, exhibits a marked pocket-like depression or recess called the laryngeal sinus. The recess passes upwards so as to undermine somewhat the false vocal cord, and its mouth is somewhat narrower than its cavity. In front it reaches forwards to the angle between the alæ of the thyroid cartilage, whilst behind it ends at the anterior border of the arytenoid cartilage.

Under cover of the forepart of the false vocal cord a small slit-like aperture may be detected; this leads upwards from the laryngeal sinus into a small diverticulum of mucous membrane, termed the **laryngeal saccule** (appendix ventriculi), which ascends between the false vocal cord and the ala of the thyroid cartilage. The laryngeal saccule is of variable extent, but as a rule it ends blindly at the level of the upper border of the thyroid cartilage.

Sometimes the saccule extends much higher, and may even reach the hinder part of the great cornu of the hyoid bone. This is of interest when considered in connexion with the extensive laryngeal pouches of the anthropoid apes.

Fig. 620.—Specimen showing a great Extension of the Saccule of the Larynx.

Lower Compartment of the Laryngeal Cavity.—This leads directly downwards into the trachea. Above it is narrow and compressed laterally, but it gradually widens out until, in its lowest part, it becomes circular, in correspondence with the trachea with which it is continuous. It is bounded by the sloping inner surfaces of the crico-thyroid membrane and by the inner aspect of the cricoid cartilage—both covered by smooth mucous membrane. In the operation of laryngotomy the opening is made through the anterior wall of this compartment.

Mucous Membrane of the Larynx.—The mucous membrane which lines the larynx is continuous above with that lining the pharynx, and below with mucous membrane of the trachea. Over the posterior surface of the epiglottis it is closely adherent, but elsewhere, above the level of the true vocal cords, it is loosely attached by submucous tissue which extends into the aryteno-epiglottidean folds. As it passes over the true vocal cords the mucous membrane is very thin, and is tightly bound down.

It is important to bear these facts in mind, because in certain inflammatory conditions the lax submucous tissue in the upper part of the larynx is liable to become infiltrated with fluid, producing what is known as œdema glottidis. This may proceed so far as to cause occlusion of the upper part of the cavity. The close adhesion of the mucous membrane to the true vocal cords,

however, prevents the œdema extending beyond the level of the rima glottidis, and the surgeon is thus able to relieve the patient by making an opening through the front part of the crico-thyroid membrane into the lower compartment of the larynx.

Above the level of the rima glottidis the laryngeal mucous membrane is extremely sensitive, and when touched by a foreign body there is an immediate response in the shape of an explosive cough. In the lower compartment of the larynx the mucous membrane is lined by columnar ciliated epithelium. Over the true vocal cords this is replaced by squamous epithelium. In the middle compartment and in the lower part of the vestibule of the larynx the columnar ciliated epithelium again reappears. The upper part of the epiglottis and the upper parts of the side walls of the vestibule are covered by squamous epithelium similar to that present in the mouth and pharynx.

The mucous membrane of the larynx has a plentiful supply of acinose glands, and in only one place, viz. over the surface of the true vocal cords, are these completely absent. For the most part the glands are aggregated in groups. The following are the localities in which these groups are especially noticeable:—(1) On the dorsal surface of the epiglottis, many of the glands piercing the cartilage; (2) around the cuneiform cartilage, where they are chiefly responsible for the elongated elevation seen in this part of the wall of the vestibule; (3) in the false vocal cord, and over the wall of the laryngeal sinus and the laryngeal saccule.

LARYNGEAL MUSCLES.

Under this heading we do not include all the muscles which are attached to the cartilages of the larynx. Thus the inferior constrictor muscles of the pharynx, although attached to both cricoid and thyroid cartilages, and the stylo-pharyngeus muscle on each side, although inserted in part into the thyroid cartilage, properly belong to the pharynx. Of the laryngeal muscles proper two are attached to the oblique line of the thyroid cartilage (viz. the sterno-thyroid and thyro-hyoid), and are concerned in producing movements of the larynx as a whole. These are termed the **extrinsic muscles** of the larynx, and have been already described (p. 912). The **intrinsic muscles** of the larynx are a group of small muscles which help to build up the laryngeal wall and which move the laryngeal cartilages on each other. One passes between the cricoid and thyroid cartilages—the **crico-thyroid muscle**; two pass between the cricoid and arytenoid cartilages—the **crico-arytenoideus posticus** and **crico-arytenoideus lateralis**; one, in the lateral wall of the larynx, under cover of the ala of the thyroid cartilage, passes between the thyroid and the arytenoid cartilages—the **thyro-arytenoid**. These muscles are in pairs. One muscle only, which connects the two arytenoid cartilages, and which is termed in consequence the **arytenoideus**, is single. In addition to these, some muscular fibres which enter the aryteno-epiglottidean fold and reach the epiglottis require to be considered. These constitute the **thyro-ary-epiglottidean muscle**.

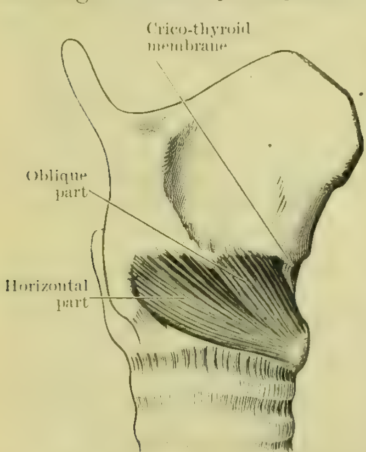


FIG. 621.—THE CRICO-THYROID MUSCLE.

The **crico-thyroid muscle** (musculus crico-thyreoideus) is placed on the cricoid cartilage, and bridges over the crico-thyroid interval. Taking origin from the lower border and outer surface of the anterior arch of the cricoid cartilage, its fibres spread out in an upward and backward direction, and are inserted into the inner surface and lower margin of the thyroid cartilage, and also into the anterior aspect of its inferior cornu. As a general rule it is divided into two parts, viz.: (1) an **anterior** or **oblique part**, composed of those fibres which are inserted into the ala of the thyroid cartilage; and (2) a **posterior** or **horizontal part** formed of those fibres which are inserted into the inferior cornu of the thyroid cartilage. It is closely associated with the inferior constrictor muscle of the pharynx, and sometimes shows a certain amount of continuity with it.

The **posterior crico-arytenoid muscle** (musculus cricoarytænoideus posterior) is somewhat fan-shaped (Fig. 623, p. 920). It springs by a broad origin from the depression which is present on the posterior lamina of the cricoid cartilage on each side of the mesial ridge, and its fibres converge to be inserted into the posterior surface of the processus muscularis of the arytenoid cartilage. In pursuing its upward and outward course on the back of the cricoid cartilage its fibres show different degrees of obliquity. The uppermost fibres are short and nearly horizontal; the intermediate fibres are the longest, and are very oblique; whilst the lowest fibres are almost vertical in their direction.

The **lateral crico-arytenoid muscle** (musculus cricoarytænoideus lateralis) is triangular in form and smaller than the preceding muscle (Fig. 622). It springs from the upper border of the lateral part of the anterior arch of the cricoid as far back as the facet which supports the base of the arytenoid cartilage. A few of its fibres also take origin from the lateral part of the crico-thyroid membrane, to which its deep surface is applied. From this attachment its fibres run backwards and upwards, and converge to be inserted into the anterior surface of the processus muscularis of the arytenoid cartilage. The superficial or outer surface of this muscle is covered by the lower part of the ala of the thyroid cartilage and by the upper part of the crico-thyroid muscle.

The **thyro-arytenoid muscle** (musculus thyreoarytænoideus) is placed in the lateral wall of the larynx under cover of the ala of the thyroid cartilage (Fig. 622). Its lower border is contiguous with, and generally inseparably blended with, the upper margin of the lateral crico-arytenoid muscle, so that the two muscles form a more or less continuous sheet. The thyro-arytenoid muscle is usually described as consisting of a superficial and a deep part, termed respectively the thyro-arytenoideus externus and the thyro-arytenoideus internus. As a rule these parts are more or less completely united, and can only be isolated from each other by artificial means.

The **thyro-arytenoideus externus** is a broad muscular layer which lies immediately subjacent to the ala of the thyroid cartilage. Its lower border is in contact with the lateral crico-arytenoid muscle, whilst its upper border is placed at a higher level than the true vocal cord. The upper part of the muscle is therefore in relation to the wall of the sinus of the larynx. The thyro-arytenoideus externus arises in front from the lower half of the inner surface of the ala of the thyroid cartilage, close to the angle, and also from the lateral part of the crico-thyroid membrane, on which it to some extent lies. Its fibres pass backwards, and are inserted into the outer border and muscular process of the arytenoid cartilage, a certain number, however, turning round this cartilage, and becoming continuous with the transverse fibres of the arytenoideus muscle.

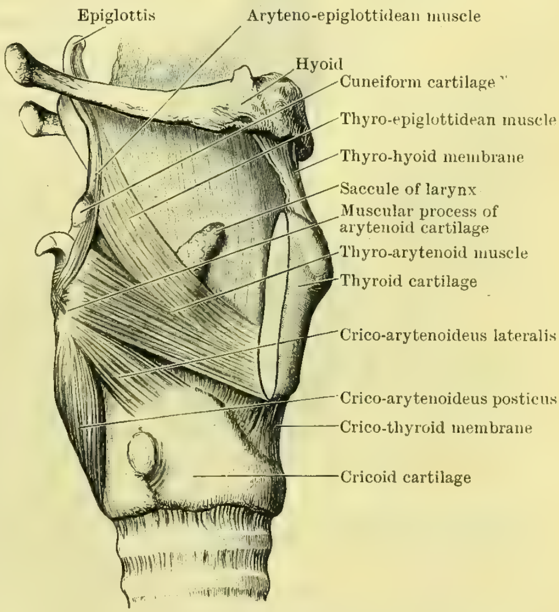


FIG. 622.—DISSECTION OF THE MUSCLES IN THE LATERAL WALL OF THE LARYNX.

The right ala of the thyroid cartilage has been removed.

A considerable number of the uppermost fibres of the thyro-arytenoideus externus, as they proceed backwards, curve upwards so as to form a thin band which reaches the aryteno-epiglottidean fold and the margin of the epiglottis. These constitute the **thyro-epiglottidean muscle**.

The **thyro-arytenoideus internus** is a slender, three-sided, muscular band which

is applied to the outer aspect of the true vocal cord, and receives its prismatic form from this adaptation. It arises in front from the angular depression between the two alæ of the thyroid cartilage, and is inserted behind into the outer aspect of the processus vocalis and also into the adjoining depressed part of the antero-external surface of the arytenoid cartilage. The thyro-arytenoideus internus is somewhat thicker behind than in front. This is due to the fact that, whilst all the fibres which compose it are attached to the arytenoid cartilage, only a certain proportion obtain attachment in front to the thyroid cartilage. A large number of the deeper fibres are directly fixed at different points to the outer side of the true vocal cord. These constitute the **ary-vocalis muscle** (Ludwig).

The thyro-arytenoideus is a very complicated muscle, and the above description can only be regarded as conveying in a general way what may be regarded as the more usual arrangement of its fibres. It is subject to much variation and to very different degrees of development in different subjects. As a rule it is possible to trace from both parts of the muscle fibres which are carried obliquely upwards over the sinus, and to some extent also over the sacculus laryngis. Further, an additional part, termed the **thyro-arytenoideus superior**, is not infrequently present. This is a slender band which arises from the inner aspect of the ala of the thyroid cartilage close to the notch, and passes backwards and downwards to find insertion into the lateral border of the arytenoid cartilage immediately above the processus muscularis.

The **arytenoideus muscle** is composed of two portions—a superficial part, termed the arytenoideus obliquus, and a deeper part, called the arytenoideus transversus.

The **arytenoideus obliquus** consists of two bundles of muscular fibres, each of which springs from the posterior aspect of the muscular process of the arytenoid cartilage. From these points the two fleshy slips proceed upwards and inwards, and cross each other in the mesial plane like the two limbs of the letter X. Reaching the summit of the arytenoid cartilage on each side, many of the fibres are inserted into it, whilst the remainder are prolonged round it into the aryteno-epiglottidean fold. Here they receive the name of the **aryteno-epiglottidean muscle**, and as they approach the epiglottis they are joined by the fibres of the thyro-epiglottidean muscle. The oblique arytenoid muscles may therefore be regarded as forming a rudimentary sphincter muscle for the superior aperture of the larynx. Each bundle, starting from the base of one of the arytenoid cartilages, is prolonged into the aryteno-epiglottidean fold of the opposite side, and within this to the margin of the epiglottis. The **arytenoideus transversus** is an unpaired muscle. It is composed of transverse fibres which bridge across the interval between the two arytenoid cartilages, and occupy their posterior concave surfaces. To a large extent these fibres are inserted into the posterior aspect of the outer border of each arytenoid cartilage, but many turn round this border and become continuous with the fibres of the thyro-arytenoid muscle. It follows from this that the arytenoideus transversus and the two thyro-arytenoid muscles are sometimes spoken of as the sphincter of the glottis.

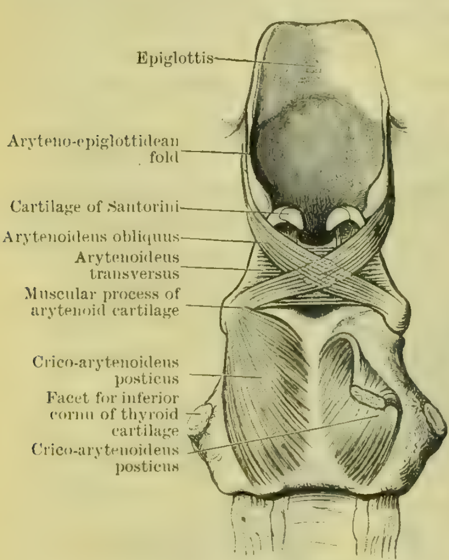


FIG. 623.—DISSECTION OF THE MUSCLES ON THE POSTERIOR ASPECT OF THE LARYNX.

Action of the Laryngeal Muscles.—By the action of the laryngeal muscles the position and tension of the true vocal cords are so influenced that, during the passage of air through the larynx, the tone and the pitch of the voice is determined. *Tension* of the true vocal cords is produced by the contraction of the two **crico-thyroid muscles**. The anterior or oblique portions of the muscles pull the lower border of the thyroid cartilage downwards, whilst the posterior horizontal portions, through their insertion into the

inferior cornua, draw the thyroid cartilage forwards, thereby increasing the distance between the angle of the thyroid cartilage and the vocal processes of the arytenoid cartilages. When the crico-thyroid muscles cease to contract, the relaxation of the cords is brought about by the elasticity of the ligaments. The **thyro-arytenoid muscles** must be regarded as antagonistic to the crico-thyroid muscles. When they contract they approximate the angle of the thyroid cartilage to the arytenoid cartilages, and still further relax the true vocal cords; and when they cease to act the elasticity of the ligaments of the larynx again restore the state of equilibrium. The ary-vocales muscles, by the insertion of their fibres into the true vocal cords, may tighten portions of these cords, whilst they relax at the same time the parts behind.

The *width of the rima glottidis* is regulated by the **arytenoideus muscle**, which draws together the two arytenoid cartilages, and this may be done so effectually that the inner surfaces of these cartilages come into contact; the glottis respiratoria is thus completely closed. The lateral and posterior crico-arytenoid muscles also modify the width of the rima glottidis. When they act together they assist the arytenoideus muscle in closing the glottis, but when they act independently they are antagonistic muscles. Thus the **posterior crico-arytenoid muscles,** by drawing the muscular processes of the arytenoid cartilages outwards and backwards, swing the processus vocales and the vocal cords outwards, and thereby open the rima. The **lateral crico-arytenoid muscles** act in exactly the opposite manner. By drawing the muscular processes of the arytenoid cartilages forwards and inwards, they approximate the processus vocales and close the rima.

Closure of the Larynx during Deglutition.—But the muscles of the larynx have another function to perform besides vocalisation and regulating the amount of air passing to and fro through the glottis. During deglutition it is requisite that the communication between the pharynx and larynx should be closed, so as to prevent the fluid or solid parts of the food entering the respiratory passages. Formerly it was believed that this was effected by the folding back of the epiglottis; that in fact the epiglottis, during the passage of the food, is applied like a lid over the entrance into the vestibule of the larynx. The observations of Professor Anderson Stuart would seem to indicate that this view is incorrect. According to Professor Stuart it is not the anterior wall of the vestibule which moves; the epiglottis stands erect, whilst the posterior wall formed by the arytenoids is carried forwards. In the process of closing the laryngeal entrance the arytenoid cartilages are closely approximated, glide forwards, and are then inclined towards the epiglottis. The result of this is that the laryngeal opening is converted into a T-shaped fissure. The mesial limb of the T is formed by the interval between the closely-applied arytenoid cartilages, whilst the cross limb, which lies in front, is bounded anteriorly by the epiglottis and behind by the aryteno-epiglottidean folds. The apices of the arytenoid cartilages, with the cartilages of Santorini, are pressed against the cushion of the epiglottis, whilst the lateral margins of the epiglottis are pulled backwards so as to make the transverse limb of the fissure distinctly concave in a backward direction. The muscles chiefly concerned in producing these movements are the external thyro-arytenoid and the transverse arytenoid muscles. These form a true sphincter vestibuli. The thyro-ary-epiglottidean muscles also come into play. They pull upon the epiglottis so as to produce tight application of its cushion to the arytenoid cartilages and the cartilages of Santorini, and they also curve its margins backwards so as to increase its posterior concavity.

Vessels and Nerves of the Larynx.—Two branches of the vagus nerve, viz. the superior laryngeal and the recurrent laryngeal nerves, supply the larynx. The superior laryngeal divides into the internal and external laryngeal branches. The **external laryngeal nerve** supplies the crico-thyroid muscle; whilst the **internal laryngeal nerve** enters the larynx by piercing the lateral part of the thyro-hyoid membrane to supply the laryngeal mucous membrane. The **recurrent laryngeal nerve** reaches the larynx from below, and supplies all the intrinsic laryngeal muscles with the exception of the crico-thyroid.

The **superior laryngeal artery,** a branch of the superior thyroid, accompanies the internal laryngeal nerve; whilst the **inferior laryngeal artery,** which springs from the inferior thyroid, accompanies the recurrent laryngeal nerve. These two vessels ramify in the laryngeal wall and supply the mucous membrane, the glands, and muscles.

Growth-Alterations, and Sexual Differences in the Larynx.—A considerable amount of variation may be noticed in the size of the larynx in different individuals. This is quite independent of stature, and explains to a great extent the difference in the pitch of the voice which is observable in different persons. But quite apart from these individual variations, there is a marked sexual difference in the size of the larynx. The male larynx is not only absolutely but also relatively larger than the female larynx. This is noticeable in all its diameters, but more particularly in the antero-posterior diameter,

and to a large extent the increase in the latter direction is produced by the strong development of the laryngeal angle or pomum Adami in the male. The great antero-posterior diameter of the male larynx necessarily implies a greater length of the vocal cords and a lower or deeper tone of the voice than in the female.

In the newly-born child the larynx, in comparison with the rest of the body, is somewhat large (C. L. Merker), and it continues to grow slowly and uniformly up to the sixth year of childhood. At this period there is a cessation of growth, which persists until puberty is reached, and then a stage of active growth supervenes. Up to this time the larynx in both sexes is similar in its characters, and although the growth which now occurs affects both the male and the female larynx, it is much more rapid and much more accentuated in the male than in the female. As a result of this the voice of the male breaks and assumes its deep tone.

It is interesting to note that the growth activity of the larynx at puberty is intimately connected with the development of the sexual organs. In an individual who has been castrated when young the larynx attains a size which exceeds that of the female only to a very small degree, and the high pitch of the voice is retained.

Appearance presented by the Interior of the Larynx when examined by the Laryngoscope.—When the cavity of the larynx is illuminated and examined by the laryngoscopic mirror the parts which surround the superior aperture of the larynx, as well as the interior of the organ, come into view. Not only this, but when the vocal cords are widely separated it is possible to inspect the interior of the trachea as low down as its bifurcation.

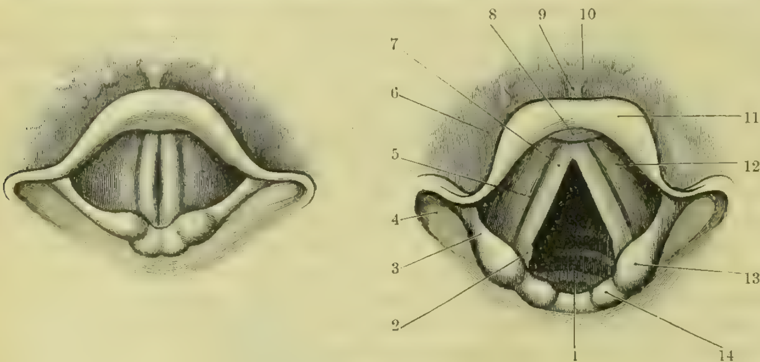


Fig. 624.—Cavity of the Larynx, as seen by means of the laryngoscope.

A. The rima glottidis closed. B. The rima glottidis widely open.

1. Rings of the trachea.
2. Processus vocalis of the arytenoid cartilage.
3. Aryteno-epiglottidean fold.
4. Sinus pyriformis.
5. Laryngeal sinus.
6. Vallecula.
7. True vocal cord.
8. Cushion of epiglottis.
9. Middle glosso-epiglottidean fold.
10. Base of tongue.
11. Epiglottis.
12. False vocal cord.
13. Cuneiform tubercle.
14. Tubercle of Santorini.

In such an examination the arched upper border of the epiglottis constitutes a conspicuous object, whilst, behind this, the bulging on the anterior wall of the vestibule, formed by the cushion of the epiglottis, may constitute a feature of the picture. The middle glosso-epiglottidean ligament, with the vallecular fossa on either side of it, can also be inspected in the interval between the epiglottis and the base of the tongue. The sharp ary-epiglottidean folds are clearly visible, and in the back portion of each of these can be seen the two prominent tubercles which are formed by the enclosed cuneiform cartilage and the cartilage of Santorini. Behind these tubercles is the posterior wall of the pharynx, whilst to their outer side the deep sinus pyriformis may be seen. In the interior of the larynx the false and the true vocal cords are easily recognised, and the interval between the false and the true cord, or, in other words, the entrance into the laryngeal sinus, appears as a dark line on the side wall of the larynx. The false vocal cords are red and fleshy-looking; the true vocal cords during phonation are tightly stretched and pearly white—the white colour being usually more apparent in the female than in the male. The outline and yellowish tinge of the processus vocalis at its attachment to the true vocal cord, as well as, to a slight extent, the outline of the fore part of the base of the arytenoid cartilage, can in a successful laryngoscopic examination be made out. The true vocal cords during ordinary inspiration are seldom at rest, and with the laryngoscope their movements may be studied. It should be borne in mind that the picture afforded by the laryngoscope does not give a true idea of the level at which the different parts lie. The cavity appears greatly shortened, and its depth diminished.

THE TRACHEA.

The **trachea** or **windpipe** is a wide tube which is kept permanently patent by a series of cartilaginous rings embedded in its wall. These rings are deficient posteriorly, and consequently the tube is not completely cylindrical: its hinder wall is flattened. The trachea begins above at the lower border of the cricoid

cartilage, and opposite the lower margin of the sixth cervical vertebra. From this it extends downwards through the lower part of the neck into the superior mediastinum of the thorax, in which it ends at the level of the upper border of the fifth dorsal vertebra by dividing into the right and left bronchus. The length of the trachea in the male is from four to four and a half inches, and in the female from three and a half to four inches, but even in the same individual it varies considerably in length with the movements of the head and neck.

The lower end of the trachea is fixed in position. This is a necessary provision to prevent dragging on the roots of the lungs during movements of the head and neck. The remainder of the tube is surrounded by a quantity of loose areolar tissue, and possesses a considerable amount of mobility. Further, its wall is highly elastic, and thus when the head is thrown back the tube elongates through stretching, and when the chin is depressed its length is diminished by the recoil of its wall.

The trachea does not present an absolutely uniform calibre throughout its whole length. About its middle it exhibits a slight expansion or dilatation, and from this the calibre diminishes in an upward and a downward direction. Close to the bifurcation it is again slightly expanded (Braune and Stahel).

These differences in the calibre of the tube are in some measure determined by the surroundings of the trachea. The upper part is apparently narrowed through its being clasped by the thyroid body. Further, a short distance above the bifurcation an impression, sometimes strongly marked, is frequently seen on the left side of the trachea. This is due to the close contact of the aortic arch as it passes backwards against this part of the tube. It is therefore probable that the second slight diminution in calibre which is described by Braune and Stahel is produced by the proximity of the aorta. Lejars gives the average antero-posterior diameter of the trachea in the living person as 11 mm., and the transverse diameter as 12·5 mm. In the dead subject the lumen of the tube is considerably greater.

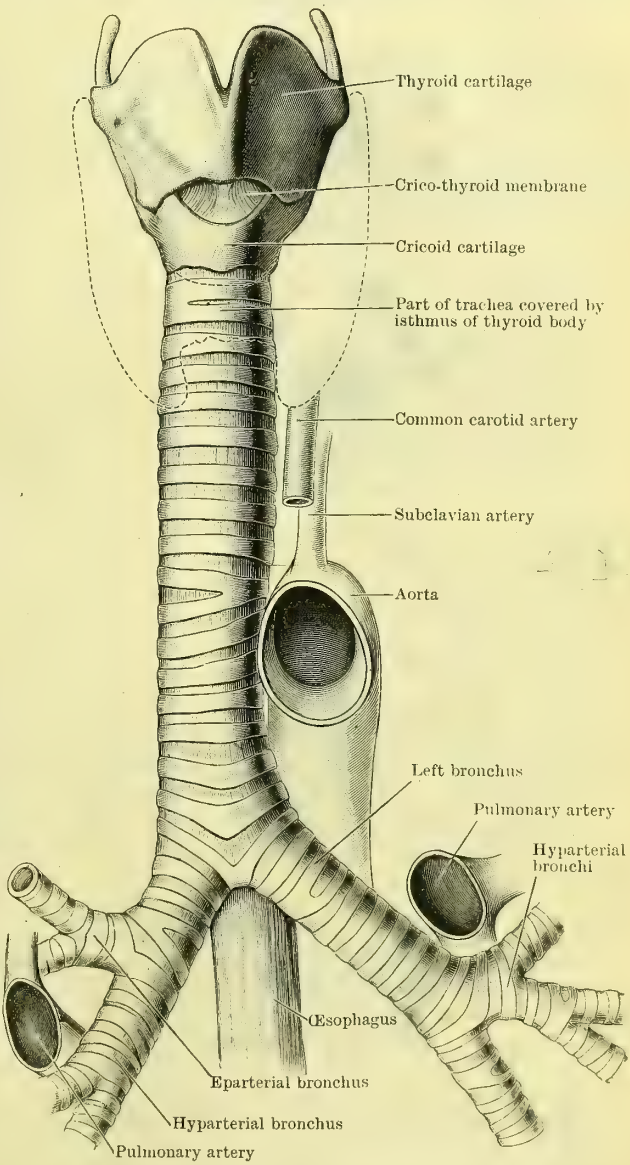


FIG. 625.—THE TRACHEA AND BRONCHI.
The thyroid body is indicated by a dotted line.

The trachea adheres rigorously to the median line except towards its lower end, where it deviates very slightly to the right. As it descends it recedes rapidly from the surface. This is due to its following the curvature of the vertebral column, from which it is separated by the œsophagus alone:

Relations of the Trachea.—In the study of the relations of the trachea it is convenient to consider it in the two stages of cervical and thoracic.

When the chin is held so that the face looks forwards the **cervical part** of the trachea measures from 2 to $2\frac{1}{2}$ inches in length; but when the head is thrown back the length is considerably increased. In its upper part the trachea is clasped by the thyroid body, the isthmus of which is applied to its anterior surface, and covers the second, third, and fourth rings, whilst on each side the lateral lobe of the same body is applied to its lateral surface, and extends downwards as low as the fifth ring. On either side of the cervical trachea is the common carotid artery, whilst the recurrent laryngeal nerve ascends in the groove between the trachea and the œsophagus. Posteriorly the trachea is in relation to the œsophagus, which intervenes between it and the bodies of the vertebræ, and deviates somewhat to the left as it descends.

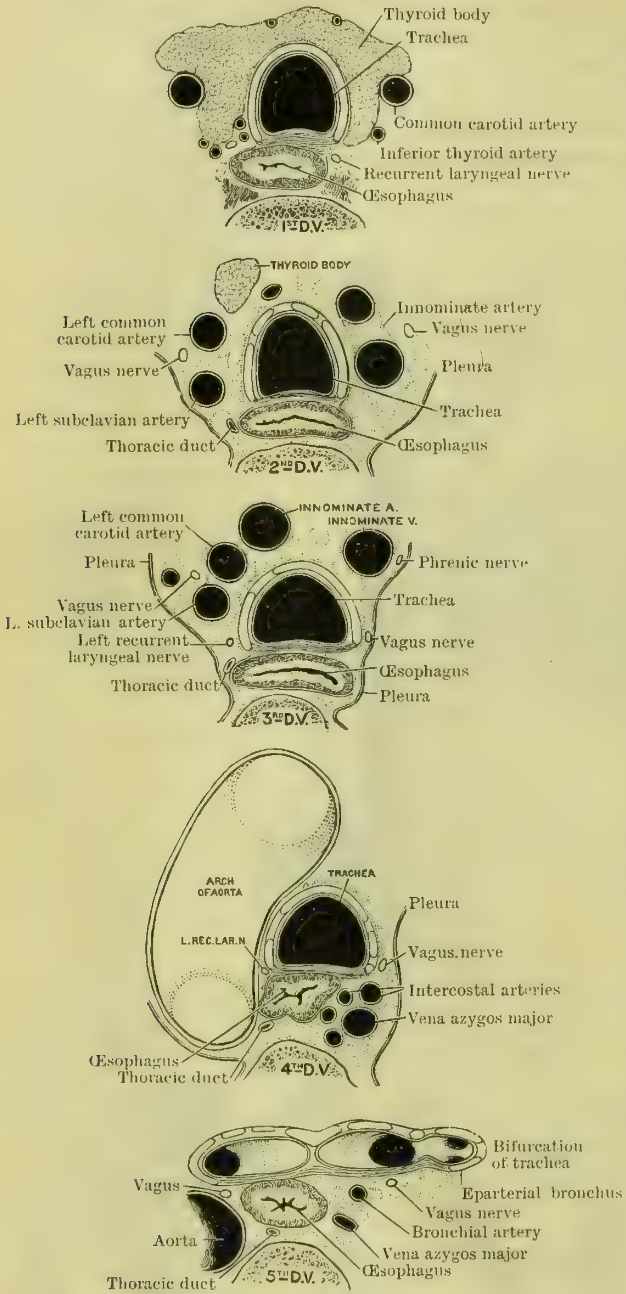


Fig. 626.—Transverse Sections through the trachea and its immediate surroundings at the level of each of the upper five dorsal vertebræ.

In addition to the isthmus of the thyroid body two thin muscular strata, composed of the sterno-hyoid and sterno-thyroid muscles, and also the deep fascia and integument, separate the cervical trachea from the surface. In the middle line of the neck there is a narrow diamond-shaped space between the inner margins of these muscles, within which the trachea is merely covered by the integuments and fasciæ. It is important to note that in the lower part of the neck the deep cervical fascia is in two layers—viz. a strong stratum applied to the anterior surface of the sterno-hyoid and sterno-thyroid muscles, and a weaker superficial layer stretching across between the two sterno-mastoid muscles. Beneath these muscular and fascial layers the inferior thyroid veins descend on the surface of the trachea, and sometimes the occasional thyroidea ima artery passes upwards in front of the tube. At the upper border of the manubrium sterni the innominate artery may be seen crossing the trachea obliquely.

The **thoracic part** of the trachea is situated in the back part of the superior

mediastinum, being separated from the bodies of the vertebræ by the œsophagus alone. Immediately above its bifurcation the deep cardiac plexus of nerves is placed in front and on either side of the trachea. At the level of the fourth dorsal vertebra the aortic arch is very intimately related to it. At first in front of the tube, the aortic arch passes backwards in close contact with its left side. The three great vessels which spring from the aortic arch are also placed in close proximity to the trachea. The innominate and left common carotid arteries, at first in front, gradually diverge as they proceed upwards and come to lie on either side of the tube—the innominate to the right, and the left common carotid to the left. In front of these vessels are the left innominate vein and the remains of the thymus body. On the right side the thoracic part of the trachea is in relation to the right vagus nerve, and is clothed by the right mediastinal pleura; on the left side are the left subclavian artery and the left recurrent laryngeal nerve.

Structure of the Wall of the Trachea.—The wall of the trachea and bronchi is composed of (1) a fibro-elastic membrane in which the cartilaginous rings are embedded; (2) within this, and on the posterior aspect of the tube, a layer of muscular tissue, termed the musculus trachealis; and (3) the lining mucous membrane.

The **fibro-elastic membrane** is strong and dense, and, passing round the whole circumference of the tube, it becomes continuous superiorly with the perichondrium which invests the cricoid cartilage. Embedded in its substance are the series of **cartilaginous rings.** These vary in number from 15 to 20, and are composed of hyaline cartilage. They are horseshoe-shaped, the posterior fourth of the circumference being deficient, so that behind, each ring ends in two rounded extremities. The external surface of a tracheal ring is flat and even, and does not project much beyond the level of the membrane in which it is embedded; the inner surface, however, is convex in the vertical direction, and consequently it bulges slightly into the lumen of the trachea. The intervals between the rings are somewhat narrower than the rings themselves, and neighbouring rings frequently show a more or less complete fusion, whilst others present other irregularities, such as a tendency to bifurcate. The lowest ring is specially adapted to the tracheal bifurcation. In the middle line in front it inclines downwards, and from this median peak a cartilaginous strip is carried backwards in the fork between the two bronchi.

The **musculus trachealis** is a continuous layer of involuntary muscular tissue placed in the posterior part of the wall in front of the fibro-elastic membrane. The muscular bundles are arranged transversely, and are attached to the extremities of the rings, and also to the deep surface of the rings for a short distance beyond their extremities. In the intervals between the rings the transverse muscular bundles are attached to the fibro-elastic membrane. It is evident that, by its contraction, this muscle will reduce in a marked degree the lumen of the tube.

The **mucous membrane** is laid smoothly over the interior of the tube upon a layer of submucous areolar tissue. Lymphoid tissue enters largely into the composition of the tracheal mucous membrane, and its inner surface is lined by columnar ciliated epithelial cells. The action of the cilia exercises an important influence in producing an upward movement of the mucus which is present on the surface of the mucous membrane.

Numerous longitudinal bundles of elastic tissue are present in the posterior wall of the trachea, more particularly in its lower part, between the mucous membrane and the musculus trachealis.

In connexion with the mucous membrane there is a plentiful supply of **acinose mucous glands.** These are placed in the submucous tissue, and also on the posterior aspect of the tube on the exterior of the musculus trachealis as well as amidst its muscular bundles. They send their ducts to the surface of the mucous membrane, where they open by trumpet-shaped mouths.

THE BRONCHI.

The two **bronchi** proceed obliquely downwards and outwards from the termination of the trachea, each towards the hilus of the corresponding lung. Like the trachea they are kept permanently patent by the presence of cartilaginous rings in their walls. These rings are deficient posteriorly, so that the bronchi exhibit a flattened posterior surface in every respect similar to the trachea. The two bronchi differ from each other, not only in the relations which they present to surrounding structures, but also in length, in width, and in the direction which they pursue (Fig. 625, p. 923).

The first collateral branch arises from the right bronchus, much nearer the trachea than in the case of the left bronchus. It is this which determines the length of these primary divisions of the trachea, and although there is much variation in this matter, it may be said that, as a rule, the left bronchus is at least twice as long as the right bronchus. According to Henle there are from six to eight rings in the right and from nine to twelve rings in the left bronchus. A marked difference is also noticeable in the calibre of the two tubes. The right bronchus is wider than the left in the proportion of 100 : 78·4 (Braune and Stahel), and this asymmetry is clearly due to the fact that the right lung is more bulky than the left. The right bronchus, as it passes towards the hilus of the right lung, takes a more vertical course than the left bronchus. It therefore lies more in the line of the trachea, and to this, as well as to its greater width, is due the greater tendency which foreign bodies exhibit, when introduced into the trachea, to drop into the right in preference to the left bronchus. The average angle which the right bronchus forms with the median plane is 24·8°, whilst the angle formed by the left bronchus with the median plane is 45·6°. The more horizontal course of the left bronchus is probably determined by the marked projection of the heart to the left side of the mesial plane (Merkel).

Relations of the Bronchi.—Arching forwards over the right bronchus is the vena azygos major, whilst arching backwards over the left bronchus there is the arch of the aorta. Occupying the interval between the bronchi there is a cluster of bronchial lymphatic glands, and an irregular chain of similar glands is carried along each tube towards the lung. On the posterior aspect of each bronchus the vagus nerve breaks up into the posterior pulmonary plexus, whilst the left bronchus, as it proceeds downwards and outwards, crosses in front of the œsophagus and the descending thoracic aorta. But perhaps the most interesting relation is that presented on each side by the corresponding pulmonary artery. On the left side the pulmonary artery crosses in front of the left bronchus above the level of its first collateral branch, and then turns round its outer side to gain its posterior aspect. All the left bronchial branches, therefore, are placed below the left pulmonary artery, and are in consequence termed **hyparterial**. The right pulmonary artery, on the other hand, crosses in front of the continuation of the right bronchus below its first collateral branch. This branch is therefore termed the **eparterial bronchus**, whilst all the others are classified as hyparterial.

Structure of the Walls of the Bronchi.—The walls of the bronchi present a structure similar to that seen in the trachea.

THE THORACIC CAVITY.

A central vertical partition, termed the **mediastinum thoracis**, which extends from the vertebral column behind to the anterior thoracic wall in front, subdivides the thoracic cavity into two large lateral chambers which contain the lungs. From the fact of each of these chambers being lined by an extensive and separate serous membrane called the **pleura**, they receive the name of the **pleural cavities**.

The mediastinum or intervening partition is built up of several structures which lie in or in close proximity to the mesial plane. The more important of these are the heart, enveloped in its pericardium, the thoracic aorta, with the great vessels which spring from its arch, the pulmonary artery, and the great veins in the neighbourhood of the heart, the thymus gland or its remains, the trachea, œsophagus, and thoracic duct, and the pneumogastric and phrenic nerves.

The pleural cavities in which the two lungs lie comprise much the largest part of the thoracic cavity. Each is bounded *below* by the corresponding cupola of the diaphragm; and as the right cupola rises to a higher level than the left, the right pleural cavity presents a smaller vertical depth than the left. *In front*, the wall of each pleural chamber is formed by the costal cartilages and the sternum, *laterally*, by the shafts of the ribs and the intercostal muscles as far back as the angles of the ribs, *behind*, by the portions of the ribs, with the intervening intercostal muscles which lie internal to the costal angles, and *internally*, by the bodies of the vertebræ and the mediastinal partition which completely shut off the one

chamber from the other. The mediastinum is not median in position. Owing to the marked projection of the heart to the left side, and to the position of the descending thoracic aorta on the left side of the mesial plane, the left pleural chamber, although it is deeper than the right, is greatly reduced in width. The two pleural cavities, therefore, are very far from being symmetrical in form.

Each pleural cavity is completely lined by a separate serous membrane termed the **pleura.** The portion of this membrane which clothes the mediastinum or intervening partition forms the lateral boundary of a space termed the **mediastinal** or **interpleural space,** within which the parts which build up the mediastinum are placed.

THE TWO PLEURAL MEMBRANES.

The pleura or pleural membrane of each side not only lines the corresponding pleural cavity, but at the pulmonary root it is prolonged on to the lung so as to give it a complete investment. It is customary, therefore, to recognise a **visceral** or **investing part** (pleura visceralis) and a **parietal** or **lining part** (pleura parietalis). The inner surface of the membrane (*i.e.* that surface which is turned towards the interior of the cavity) is coated with squamous epithelium, and presents a smooth, glistening, and polished appearance; further, it is moistened by a small amount of serous fluid. In consequence of this the surface of the lung covered by visceral pleura can glide on the wall of the cavity, lined as it is by parietal pleura, with the least possible degree of friction. In the pathological condition known as pleurisy the surface of the membrane becomes roughened by inflammatory exudation, and the so-called "friction sounds" become evident when the ear is applied to the chest.

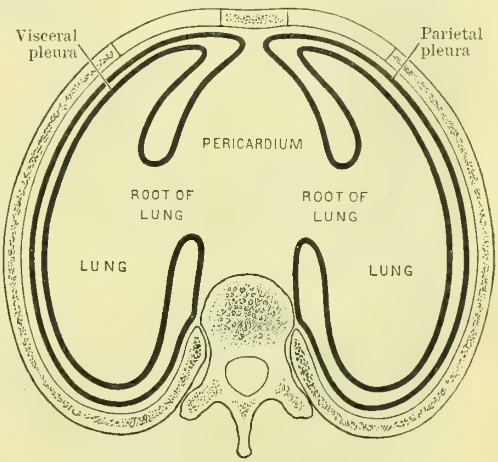


Fig. 627.—Diagram showing Arrangement of Pleural Sacs, as seen in transverse section.

Visceral Pleura.—The visceral pleura is very thin, and is so firmly bound down to the surface of the lung that it cannot be detached without laceration of the pulmonary substance, and then only in small pieces. It dips into the fissures of the lungs, lines them down to the very bottom, and thus completely separates the different lobes of the lungs from each other. The visceral pleura becomes continuous with the mediastinal part of the parietal pleura over the root of the lung, and also through the ligamentum latum pulmonis.

Parietal Pleura.—Different names are applied to the parietal pleura as it lines the different parts of the wall of the cavity in which the lung lies. Thus there is the costal pleura, the diaphragmatic pleura, the mediastinal pleura, and the cervical pleura; but it must be borne in mind that these terms are merely used for convenience in description, and the portions of the membrane so designated are all directly continuous with each other.

The **cervical pleura** rises up into the root of the neck, through the superior aperture of the thorax, and forms a dome-shaped roof for the pleural cavity. Its summit or highest point reaches the level of the lower border of the neck of the first rib; but owing to the great obliquity of the first costal arch, this point is placed from one to two inches above the anterior extremity of the first rib, and from a half to one and a half inches above the clavicle. The cervical dome of pleura is supported on the outer side by the scalenus anticus and scalenus medius muscles, whilst the subclavian artery arches over it, and lies in a groove on its inner and anterior aspect a short distance below its summit. At a lower level the innominate and subclavian veins also lie upon its inner and anterior aspects.

The cervical *cul de sac* of pleura is strengthened and held in place by an aponeurotic expansion, first described by Sibson, which is spread over it, and is attached to the inner concave margin of the first rib. This fascia is derived from a small muscular slip which takes origin from the transverse process of the seventh cervical vertebra.

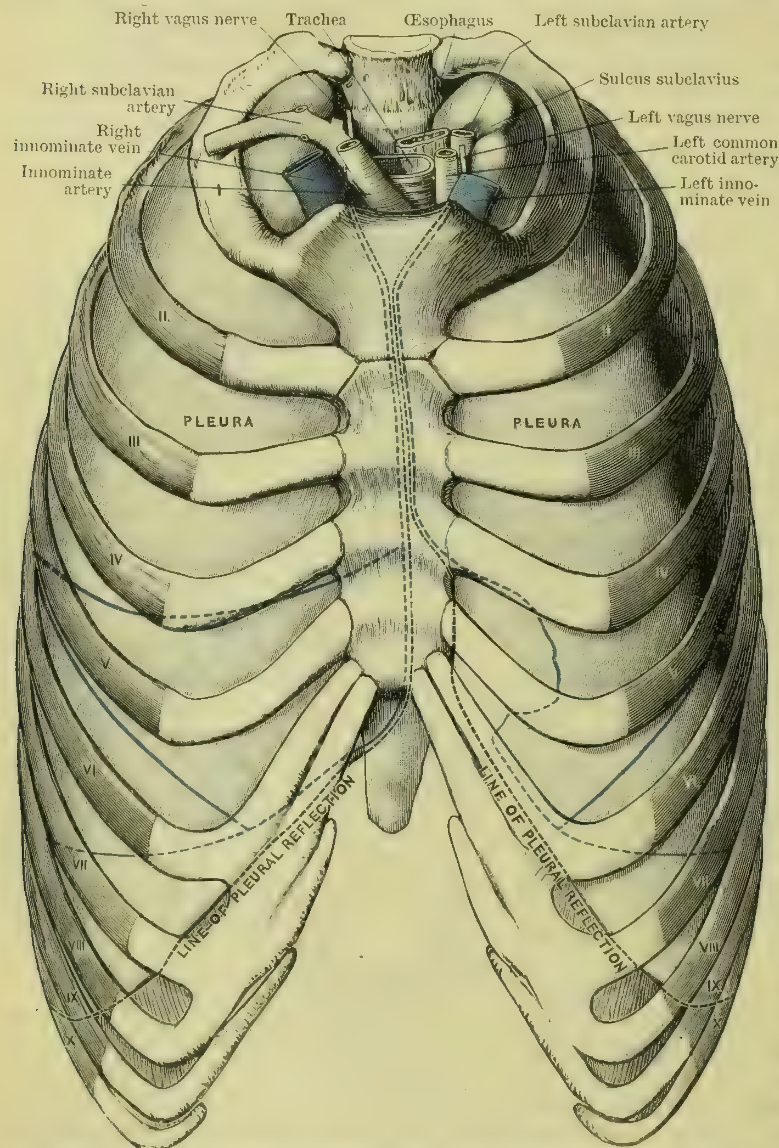


FIG. 628.—DISSECTION OF A SUBJECT HARDENED BY FORMALIN-INJECTION, to show the relations of the two pleural sacs as viewed from the front. The anterior and diaphragmatic lines of pleural reflection are exhibited by black dotted lines, whilst the outlines of the lungs and their fissures are indicated by the blue lines.

The **costal pleura** is the strongest and thickest part of the parietal pleura. It lines the deep surface of the costal arches and of the intervening intercostal muscles. In front it reaches the back of the sternum, whilst behind it is carried forwards on the bodies of the vertebræ. It is easily detached from the parts which it covers, except as it passes from the heads of the ribs on to the vertebral column. Here it is somewhat tightly bound down.

The **diaphragmatic pleura** covers the portion of the upper surface of the diaphragm which lies to the outer side of the base of the pericardium, but it does not dip down to the bottom of the narrow interval between the thoracic wall and the diaphragm. In other words, a strip of the upper surface of the diaphragm adjoining its costal attachment is left uncovered.

The **mediastinal pleura** extends backwards from the posterior surface of the anterior thoracic wall to the vertebral column, and it clothes the side of the mediastinum or partition intervening between the two pleural cavities. It is continuous with the pleura costalis of its own side, both in front and behind, along two lines which are respectively termed the **anterior** and **posterior lines of pleural reflection**; whilst below it becomes continuous with the diaphragmatic pleura of its own side at the base of the pericardium.

Above the level of the root of the lung the mediastinal pleura passes directly backwards from the sternum to the vertebral column. In this region the *left*

mediastinal pleura is applied to the arch of the aorta and the phrenic and vagus nerves; to the left innominate vein, the left superior intercostal vein, and the left common carotid and left subclavian arteries; to the œsophagus and the thoracic duct. The *right mediastinal pleura*, on the other hand, is applied, above the level of the root of the lung, to the upper part of the vena cava and right innominate vein; to the right innominate artery; to the vena azygos major, as it hooks forwards above the bronchus; to the vagus and phrenic nerves; and to the right side of the trachea.

Opposite the root of the lung, as well as in the region below it, the mediastinal pleura clothes the corresponding aspect of the pericardium, and is somewhat firmly attached to it. As the phrenic nerve passes downwards upon the pericardium it is likewise covered over by the pleura. In the region corresponding to the upper lateral aspect of the pericardium the mediastinal pleura is prolonged outwards, so as to form an investment for the root of the lung, and become continuous around the hilus of the lung with the visceral pleura. Below the root of the lung the two layers of pleura which invest it come into apposition with each other, and are prolonged downwards as a distinct fold, termed the **ligamentum latum pulmonis.** This fold stretches between the pericardium and the lower part of the inner surface of the lung, and ends below in a free border.

Behind the root of the lung and the ligamentum latum pulmonis the mediastinal pleura on the *right side* is carried backwards to the vertebral column on the œsophagus; whilst on the *left side* it is carried backwards over the descending aorta, and to a small extent, in the region immediately above the diaphragm and in front of the aorta, over the lower end of the œsophagus.

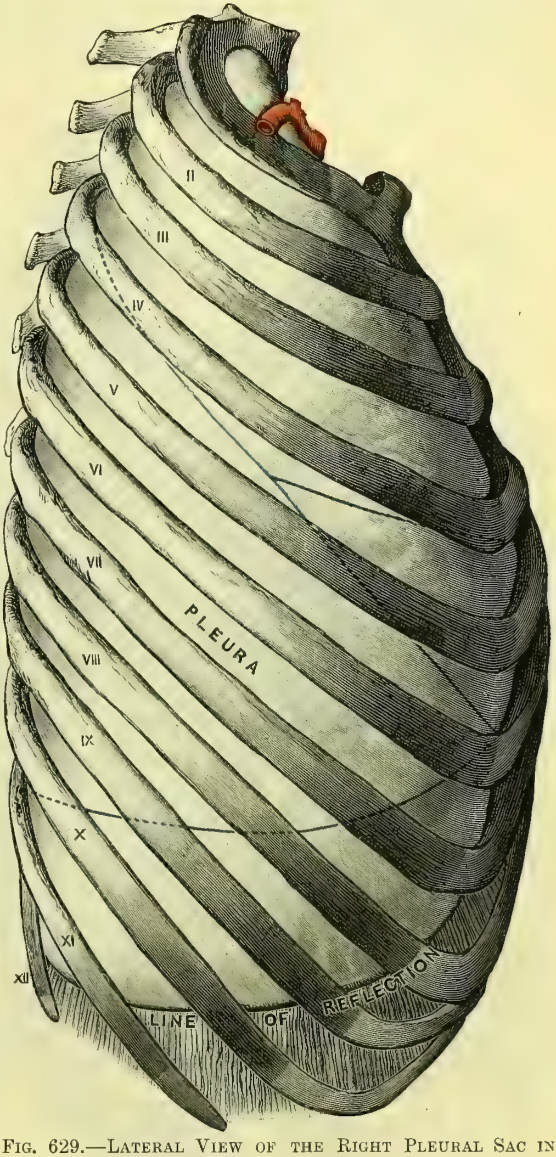


Fig. 629.—Lateral View of the Right Pleural Sac in a Subject hardened by Formalin-injection. The blue lines indicate the outline of the right lung, and also the position of its fissures.

Lines of Pleural Reflection.—These are three in number—viz. the anterior or sternal, the posterior or vertebral, and the lower or diaphragmatic. The pleural cavities are not symmetrical. The left is longer and narrower than the right, and it thus happens that the lines of pleural reflection do not accurately correspond on the two sides of the body. Further, although the posterior line of reflection is fairly constant, the other two reflection-lines are subject to marked variations in different subjects. Consequently the following description must be regarded as merely giving the average condition.

The **posterior** or **vertebral line of pleural reflection** is that along which the costal pleura turns forwards from the vertebral column so as to become the mediastinal pleura. On the *right side*, above the root of the lung, the pleura passes from the bodies of the vertebræ

on to the right side of the trachea; whilst below this level, and behind the pericardium, it passes from the vertebral bodies on to the œsophagus. On the *left side*, and above the arch of the aorta the pleura along this line of reflection is carried from the vertebral column on to the œsophagus and thoracic duct; below that level it passes on to the descending thoracic aorta. In the upper part of the chest the right and left lines of reflection are placed well apart from each other, and about equidistant from the mesial plane. As they are traced downwards they approach more closely to each other and deviate to the left, so that whilst the reflection on the *right side* takes place from the front aspect of the vertebral bodies, on the *left side* it takes place from the left aspect of the vertebral column. This is due to the position of the descending thoracic aorta.

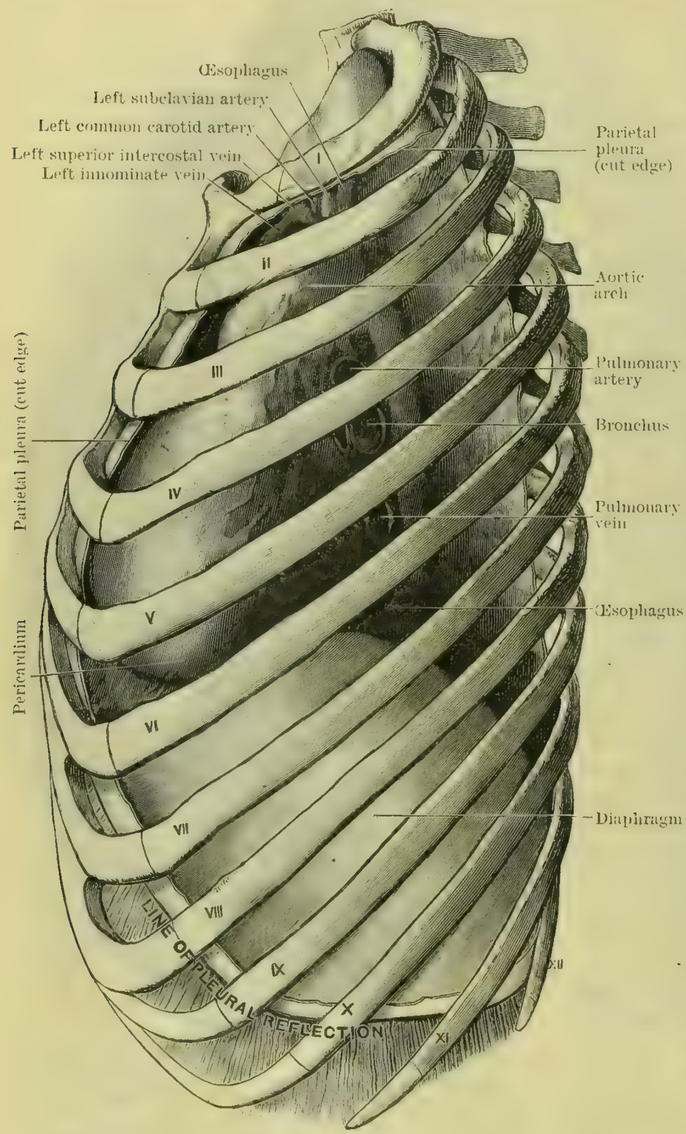


FIG. 630.—LEFT PLEURAL SAC IN A SUBJECT HARDENED BY FORMALIN-INJECTION, opened into by the removal of the costal part of the parietal pleura. The lung has also been removed so as to display the mediastinal pleura.

The **anterior line of pleural reflection** is that along which the costal pleura leaves the anterior thoracic wall to become the mediastinal pleura. The line differs somewhat on the two sides, and in both cases shows a tendency to deviate to the left (Fig. 628, p. 928). Behind the upper part of the manubrium sterni the two pleural sacs are separated from each other by an angular interval. The lines of reflection at the inlet of the thorax correspond to the sterno-clavicular joints. From these points, as they are traced downwards, they converge on the back of the manubrium, until at last they meet a short distance above the upper end of the gladiolus. Here the two sacs come into contact with each other, and the lines of reflection coincide. From this they proceed downwards on the back of the sternum, with a slight deviation to the left of the mesial plane, until a point immediately above the level of the sternal attachments of the fourth costal cartilages is reached, and here the two sacs part company. The line of reflection of the *right pleura* is continued downwards in a straight line behind the sternum until the back of the ensiform cartilage is reached, and here the sternal reflection-line passes into the right diaphragmatic reflection-line. Opposite the sternal attachment of the fourth costal cartilage the reflection-line of the *left pleura* deviates outwards on the back of the sternum, and is continued downwards at a variable distance from the right pleura. A small triangular area of pericardium is thus left uncovered by pleura, and therefore in direct contact with the anterior chest-wall. Leaving the sternum, the reflection-line of the left pleura descends

parallel and close to the left margin of the sternum behind the fourth intercostal space, the fifth costal cartilage and the fifth intercostal space, to the back of the sixth costal cartilage. Here it turns outwards and downwards, and passes into the diaphragmatic reflection-line of the left side.

From the back of the sternum the *right pleura* is reflected in the upper part of the chest on to the remains of the thymus, the right innominate vein and the vena cava, and below this directly on to the front of the pericardium. The *left pleura* is reflected from the back of the manubrium sterni on to the left innominate vein and the aortic arch, and below this directly on to the front of the pericardium.

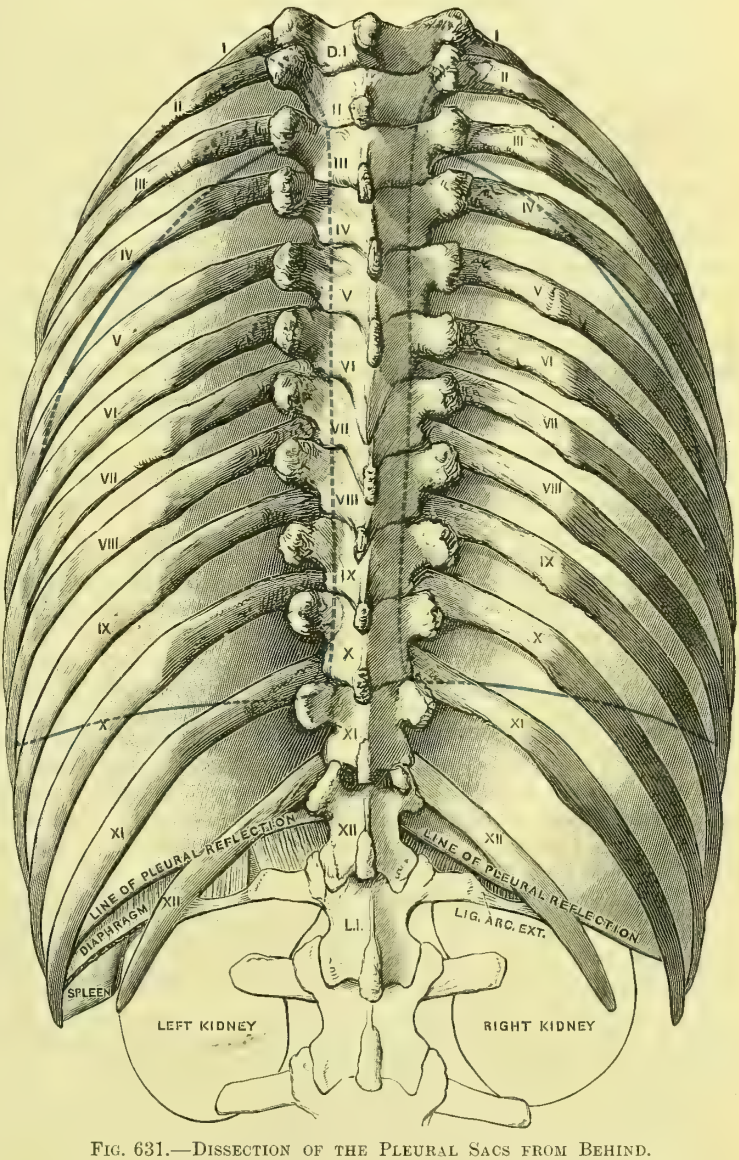


FIG. 631.—DISSECTION OF THE PLEURAL SACS FROM BEHIND.
The blue lines indicate the outlines and the fissures of the lungs.

The **diaphragmatic line of reflection** is that along which the pleura leaves the thoracic wall and is reflected on to the upper surface of the diaphragm. This reflection takes place along a curved line, which, except behind as it approaches the vertebral column, is placed a short distance above the lower border of the thoracic wall. It differs somewhat on the two sides of the body.

On the *left side* the diaphragmatic line of reflection proceeds downwards behind the ascending part of the sixth costal cartilage, crosses behind the anterior end of the sixth intercostal space and the descending part of the cartilage of the seventh rib (Fig. 630). Still continuing to descend, it passes behind the eighth costal arch at the junction between its cartilaginous and bony portions. This is a fairly constant relation on both sides of the body, and it should be noted that a vertical line drawn downwards from the nipple (mammillary line) intersects the line of pleural reflection close to the point where it presents this relation to the eighth costal arch. Beyond this point the line of diaphragmatic reflection is carried downwards and outwards across the extremities of the bony portions of the ninth and tenth ribs. As it passes under cover of the tenth rib, or it may be as it proceeds across the tenth intercostal space, the line of pleural reflection reaches its lowest point, and it is important to observe that this point lies in the mid-lateral line (*i.e.* a vertical line drawn downwards on the side of the chest midway between spine and sternum). From this it ascends slightly as it curves backwards towards the spine. Thus

it cuts across the eleventh rib and reaches the twelfth rib. The relation which it presents to the twelfth rib varies in accordance with the length of that rib. When the last rib is not abnormally short the pleura clothes its inner half, and the line of reflection falls below this portion of the rib so as to reach the spine midway between the head of the last rib and the transverse process of the first lumbar vertebra (Fig. 631). Here, therefore, the line of diaphragmatic reflection falls below the lower border of the thoracic wall, and this is a point of high practical importance. In operations upon the kidney the incision cannot be carried above the level of the transverse process of the first lumbar vertebra and the ligamentum arcuatum externum without the risk of wounding the pleura.

On the *right side* the line of diaphragmatic pleural reflection differs from that on the left chiefly in front (Fig. 629, p. 929). Here it descends to a lower level. Thus it proceeds outwards and downwards from the back of the ensiform cartilage along the posterior aspect of the ascending part of the seventh costal cartilage, and it passes beneath the eighth costal arch, as a rule, at the same point as on the left side, viz. at the junction of its cartilaginous and bony parts. From this backwards to the spine the relations are so similar to those of the left side that a separate description is unnecessary.

It is commonly stated that the left pleural sac reaches a lower level than the right. In certain cases there is no doubt that it does, but this condition is by no means the rule. In those cases where the two pleural sacs do not reach the same level at their lowest points, it is sometimes the right and sometimes the left pleura which oversteps the mark.

As already stated, the lowest point to which the pleura descends is usually found, on both sides, in the mid-lateral line where the diaphragmatic reflection-line crosses the tenth rib or the tenth intercostal space. This point can be very readily ascertained on the surface by drawing a horizontal line round the trunk at the level of the lower part of the extremity of the spinous process of the first lumbar vertebra, and noting where it is intersected by the mid-lateral line. In the majority of cases the point of intersection will correspond with the lowest part of the pleural sac. Another horizontal line opposite the spine of the last dorsal vertebra will give the level of the diaphragmatic pleural reflection in the mammillary line.[1]

Along the line of the diaphragmatic reflection a strong fascia passes from the lower uncovered part of the diaphragm, and from the costal cartilages to the surface of the costal pleura, so as to hold it firmly in its place. It may be termed the **phrenico-pleural fascia**.

MEDIASTINAL OR INTERPLEURAL SPACE.

The term mediastinal space is applied to the interval between the mediastinal portions of the two pleural sacs. In front it is bounded by the sternum, and behind by the vertebral column. It is customary to subdivide this space in a purely arbitrary manner into four portions, termed respectively superior, anterior, middle, and posterior, according to the relations which they present to the pericardium.

The **superior mediastinum** is the part of the general space which lies above the level of the pericardium. Its boundaries are the following:—*In front*, the manubrium sterni, to the posterior aspect of which are the attached lower ends of the sterno-hyoid and sterno-hyoid muscles; *behind*, the bodies of the upper four dorsal vertebræ; *below*, an imaginary and oblique plane, which extends from the lower border of the manubrium sterni backwards and upwards to the lower border of the fourth dorsal vertebra; *laterally*, the mediastinal pleura.

Within the superior mediastinal space are placed (1) the aortic arch and the three great arteries which spring from it; (2) the innominate veins and the upper part of the superior vena cava; (3) the trachea, gullet, and thoracic duct; (4) the phrenic, pneumogastric, left recurrent laryngeal and cardiac nerves; (5) the thymus gland.

The **middle mediastinum** is the wide part of the space which contains the pericardium, and lies below the superior mediastinum. In addition to the pericardium and its contents the middle mediastinum contains the phrenic nerves and their accompanying vessels.

[1] The above description represents the average results which have been obtained from the study of the pleura in a large number of subjects, eight of which were specially hardened by formalin or other re-agents for the purpose. For many of the dissections I have to thank my former assistant Dr. H. St. J. Brooks, and for others I am indebted to my present assistant Dr. C. J. Patten.

The **anterior mediastinum** is that part of the interpleural space which lies between the pericardium behind and the sternum in front. In its upper part this space can hardly be said to exist, seeing that here the two pleural sacs come into contact with each other on the anterior aspect of the pericardium; but below the level of the sternal ends of the fourth costal cartilages the left pleura falls short of the right pleura, and an interval is apparent. The only contents to be noticed in the anterior mediastinum are a few lymphatic glands and some areolar tissue, in which ramify some lymphatic vessels, and some minute twigs from the internal mammary artery.

The **posterior mediastinum** is that part of the interpleural space which is situated behind the pericardium. It may be regarded as the continuation downwards of the posterior part of the superior mediastinum, and many of the structures in the one are prolonged downwards into the other. The arbitrary upper limit of the posterior mediastinum is the lower border of the fourth dorsal vertebra. *In front* it is bounded by the pericardium, except in its lowest portion, where the anterior wall is formed by the back of the diaphragm. *Behind* it is limited by the bodies of the eight lower dorsal vertebræ, and *on each side* by the mediastinal pleura. It contains the descending thoracic aorta, the azygos veins, the thoracic duct and the œsophagus, with the two pneumogastric nerves.

Structure of the Pleura.—The pleura on each side is a closed sac, and, like other serous membranes, it is attached by its outer surface to the wall of the cavity which it lines and to the surface of the viscus which it covers. It is composed of a thin connective-tissue stratum in which bundles of fibres cross each other in various directions, and intermixed with which there is a considerable quantity of elastic tissue. On the inner surface of this there is a continuous coating of thin epithelial cells placed edge to edge. The pleura so formed is attached to the parts it lines and invests by a small amount of areolar tissue which forms a **subserous layer**. In the case of the visceral pleura the subserous tissue is continuous with the areolar tissue in the substance of the lung, and this accounts for the tight manner in which it is bound down.

The pleura is plentifully supplied with blood. This is conveyed to it by minute twigs from the intercostal arteries, the internal mammary artery, and the bronchial arteries. Lymphatic vessels also are particularly abundant in the pleura and in the subserous layer, and it is by these that excess of fluid is conveyed from its cavity. Many lymphatic vessels communicate directly with the cavity by means of excessively minute orifices termed **stomata**. Dybkowsky has shown that the lymphatics and stomata of the pleura are not equally distributed throughout the membrane. Over the ribs and on the mediastinal pleura they are absent.

THE LUNGS.

When healthy and sound each lung lies free within the corresponding pleural chamber, and is only attached by its root and the ligamentum latum pulmonis. It is not common, however, to meet with a perfectly healthy lung. Adhesions between the visceral and parietal layers of pleura, due to pleurisy, are generally present.

Like the cavities in which they are placed, the two lungs are not precisely alike. The right lung is slightly larger than the left, in the proportion of about 11 to 10. The right lung is also shorter and wider than the left lung. This difference is due to the great bulk of the right lobe of the liver, which elevates the right cupola of the diaphragm to a higher level than the left cupola, and likewise to the heart and pericardium projecting more to the left than to the right, and thus diminishing the width of the left lung.

The lung is light, soft, and spongy in texture; when pressed between the finger and thumb it crepitates, and when placed in water it floats. The elasticity of the pulmonary tissue is very remarkable. A striking demonstration of this is afforded when the thoracic cavity is opened, and the atmospheric pressure acting upon the interior and exterior of the lung is equalised. Immediately the organ collapses to about one-third of its original bulk, and it becomes impossible in such a specimen to study its proper form and dimensions.

The surface of the adult lung presents a mottled appearance. The ground

colour is a light slate-blue, but scattered over this there are numerous dark patches of various sizes, and also dark intersecting lines. The coloration of the lung differs considerably at different periods of life. In early childhood the lung is rosy-pink, and the darker colour and the mottling of the surface which appear later are due to the pulmonary substance, and chiefly the interstitial areolar tissue becoming impregnated more or less completely with atmospheric dust and minute particles of soot.

At every breath foreign matter of this kind is inhaled, but only a small proportion of it reaches the lung tissue. The greater part of it becomes entangled in the slimy mucus which coats the mucous membrane of the larger air-passages, and is gradually got rid of along with the mucus through the activity of the cilia attached to the lining epithelium. By the constant upward sweep of these a current towards the pharynx is established. The fine dust and soot particles which reach the finer recesses of the lungs, and ultimately the interstitial issue, is partly conveyed away by the lymphatic vessels to the bronchial glands, which in consequence become in many cases absolutely black. The colour of the lung, therefore, depends to some extent upon the purity of the atmosphere which is inhaled, and it thus happens that in coal-miners the surface of the lung may be very nearly uniformly black.

The fœtal lung differs in a marked degree from the lung in an individual who has breathed. After respiration is fully established, the lung soon comes to occupy almost the whole space allotted to it in the pleural cavity; in the fœtus, on the other hand, the lung is packed away at the back, and occupies a relatively much smaller amount of space in the thoracic cavity. Further, it is firm to the touch, and sinks in water. It is only when air and an increased supply of blood are introduced into the lung that it assumes the soft spongy and buoyant qualities which are characteristic of the adult lung.

Form of the Lungs.—The lungs are accurately adapted to the walls of the pleural chambers in which they are placed, and in the natural state they bear on

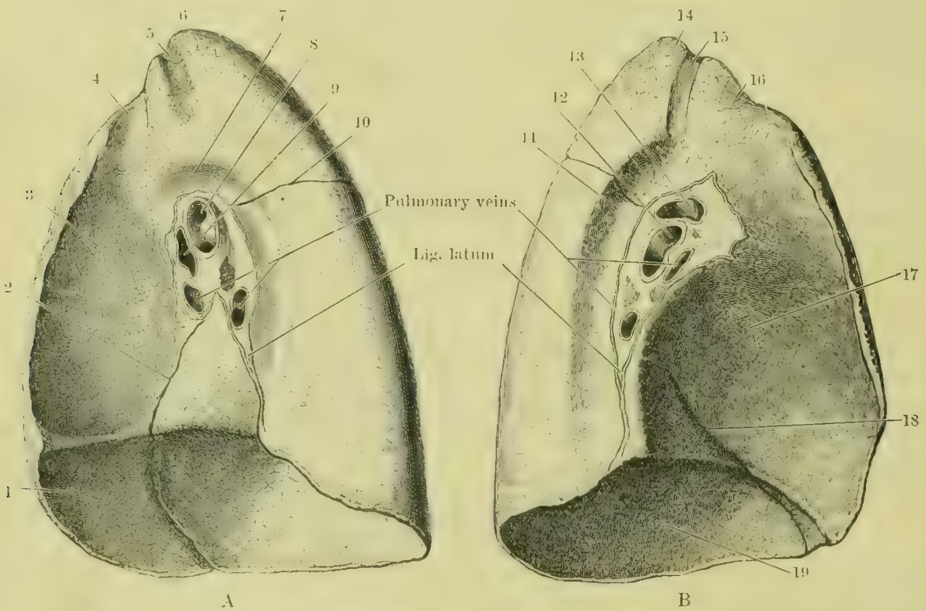


FIG. 632.—MEDIASTINAL SURFACES OF THE TWO LUNGS OF A SUBJECT HARDENED BY FORMALIN-INJECTION.
A, Right lung. B, Left lung.

1. Base.
2. Fissure.
3. Cardiac depression.
4. Groove for innominate vein.
5. Groove for innominate artery.
6. Apex pulmonis.
7. Groove for vena azygos major.
8. Eparterial bronchus.
9. Pulmonary artery (right).
10. Fissure.
11. Groove for aorta.
12. Bronchus.
13. Pulmonary artery (left).
14. Apex pulmonis.
15. Groove for left subclavian artery.
16. Groove for left innominate vein.
17. Cardiac depression
18. Fissure.
19. Base.

the surface impressions and elevations which are an exact counterpart of the irregularities on the walls of the cavity in which they lie.

When care has been taken to harden it *in situ*, each lung presents an apex

and a base, an inner and an outer surface, and an anterior and a posterior border.

The **apex pulmonis** is blunt and rounded, and rises above the level of the oblique first costal arch to the full height of the cervical dome of pleura. It therefore protrudes upwards through the thoracic inlet into the root of the neck. The subclavian artery arches outwards on its inner and anterior aspects a short distance below its summit, and a groove (sulcus subclavius) corresponding to the vessel is apparent upon it. At a lower level on the apex pulmonis a shallower and wider groove upon its inner and anterior aspects marks the position of the innominate and subclavian veins. Although these vessels impress the lung they are separated from it by the cervical pleura.

The **basis pulmonis** presents a semilunar outline, being curved around the base of the pericardium. It is adapted to the upper surface of the diaphragm, and consequently it is deeply hollowed out. As the right cupola of the diaphragm ascends higher than the left, the basal concavity of the right lung is deeper than that of the left lung. Laterally and behind, the base of each lung is limited by a salient thin margin which descends for some distance in the narrow pleural recess (sinus phrenico-costalis) between the diaphragm and the chest wall. This basal margin of the lung extends lower down on the outer side and behind than it does in front, but it falls considerably short of the bottom of the phrenico-costal sinus of pleura. Thus, after expiration, it reaches in the mammillary line the lower border of the sixth rib; in the axillary or mid-lateral line the eighth rib; whilst behind it proceeds inwards along a straight horizontal line so as to reach the vertebral column at the level of the extremity of the spine of the tenth dorsal vertebra. During respiration the thin basal margin rises and falls in the phrenico-costal sinus of the pleura, but even after the deepest breath it never reaches the lowest limit of this recess.

The bases of the lungs establish important relations with certain of the viscera which occupy the costal zone of the abdominal cavity, the diaphragm alone intervening. Thus

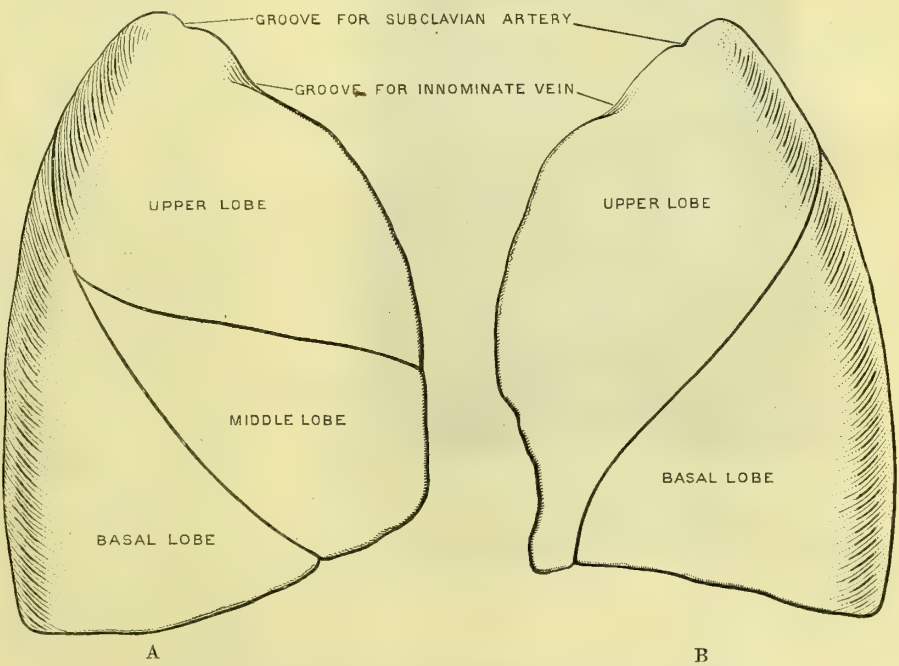


Fig. 633.—Outer or Costal Surfaces of the two Lungs.
A, Right lung. B, Left lung.

the base of the right lung rests upon the right lobe of the liver; whilst the base of the left lung is in relation to the left lobe of the liver, the fundus of the stomach, the spleen, and in some cases to the splenic flexure of the colon.

The **outer surface of the lung** (facies costalis pulmonis) is extensive and convex. It is accurately adapted to that part of the wall of the pleural cavity which is formed by the costal arches and the intervening intercostal muscles, and it presents markings corresponding to these. Thus the imprint of the ribs appear as shallow oblique grooves, while the intercostal spaces show as elongated intervening bulgings.

The **inner or mediastinal surface** of the lung (facies mediastinalis pulmonis) presents a smaller area than the outer surface. It is applied to the mediastinal septum, and presents markings in accordance with the inequalities upon this (Fig. 632, p. 934). Thus it is deeply hollowed out in adaptation to the pericardium upon which it fits. This pericardial concavity comprises the greater part of the mediastinal surface, and owing to the greater projection of the heart to the left side, it is much deeper and more extensive in the left lung than in the right lung. Above and behind the pericardial hollow is the **hilus** of the lung. This is a wedge-shaped depressed area, within which the vessels, nerves, and lymphatics, together with the bronchus, enter and leave the organ. Amidst these structures also are some bronchial glands. The hilus is surrounded by the reflection of the pleura from the surface of the lung on to the pulmonary root. Behind the hilus and pericardial area there is on each lung a narrow strip of the inner surface of the lung which is in relation to the lateral wall of the posterior mediastinum. On the *right lung* this part of the surface is depressed, and corresponds to the œsophagus; on the *left lung* it presents a broad longitudinal groove, which is produced by the contact of the lung with descending thoracic aorta, and also, close to the base, a small flattened area in front of this which is applied to the œsophagus where it pierces the diaphragm.

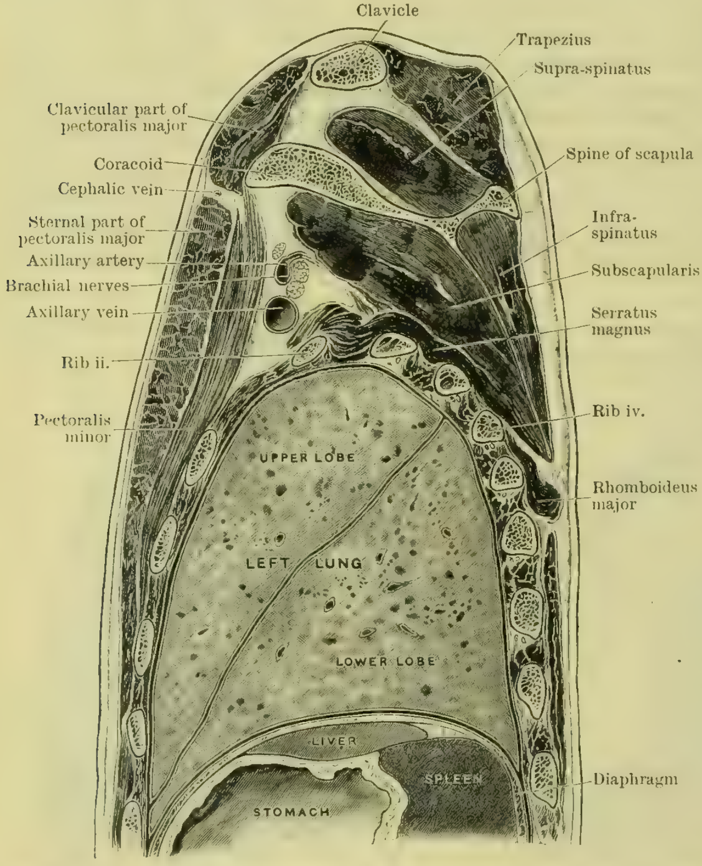


FIG. 634.—SAGITTAL SECTION THROUGH LEFT SHOULDER AND LEFT LUNG.

The portion of the inner surface of the lung which lies above the hilus and pericardiac hollow is applied to the lateral aspect of the superior mediastinum, and the markings are accordingly somewhat different on the two sides. On the *left lung* a broad deep groove, produced by the aortic arch, curves backwards over the hilus, and becomes continuous with the aortic groove on the posterior mediastinal surface. From this a narrower, deeper, and much more sharply-marked groove ascends, and turns outwards over the apex pulmonis a short distance from the summit. This is the sulcus subclavius, and it contains the left subclavian artery when the lung is in place. In front of this a shallow wide groove, also leading up to the front aspect of the apex, corresponds to the left innominate vein. In

the *right lung* the hilus is also circumscribed above by a curved groove, but this is narrow and more distinctly curved than the aortic groove on the left side. It lodges the vena azygos major as it turns forwards to join the superior vena cava. From the anterior end of the azygos sulcus a wide shallow groove extends upwards to the lower part of the front of the apex pulmonis. This is produced by the apposition of the lung with the vena cava superior and the right innominate vein. Close to the summit of the apex there is also, on its inner aspect, a sulcus for the upper end of the innominate artery.

In addition to the hilus, it must now be evident that the inner surface of each lung presents three areas which correspond respectively with (1) the middle mediastinum (*i.e.* the pericardial hollow); (2) the posterior mediastinum; and (3) the superior mediastinum; and that in each of these districts impressions corresponding to structures contained within these portions of the interpleural space may be noticed.

The **posterior border of the lung** is thick, long, and rounded. It forms the most bulky part of the organ, and occupies the deep hollow in the thoracic cavity which is placed on either side of the spine. Indeed the term "border" is somewhat inappropriate, as it forms in reality a somewhat extensive surface deeply impressed by the ribs, and not in any way marked off from the outer surface of the lung.

The **anterior border of the lung** is short and exceedingly thin and sharp. It begins abruptly above, immediately below the groove on the apex for the innominate vein, and extends down to the base, where it becomes continuous with the sharp basal border. The thin anterior part of the lung is carried forwards and inwards in front of the pericardium into the narrow pleural recess behind the sternum and costal cartilages (sinus costo-mediastinalis). The anterior border of the right lung fills up this recess completely, and in the upper part of the chest is only separated from the corresponding border of the left lung by the two layers of mediastinal pleura which are reflected backwards from the sternum to the pericardium. The anterior border of the left lung, in its lower part, shows a marked deficiency or notch (incisura cardiaca) corresponding to the apex of the heart, and where this exists the lung margin leaves a considerable portion of the pericardium uncovered, and fails to completely fill up the costo-mediastinal sinus of the pleural cavity. During respiration the anterior margin of the left lung at the incisura cardiaca advances and retreats to a small extent in this pleural sinus in front of the pericardium.

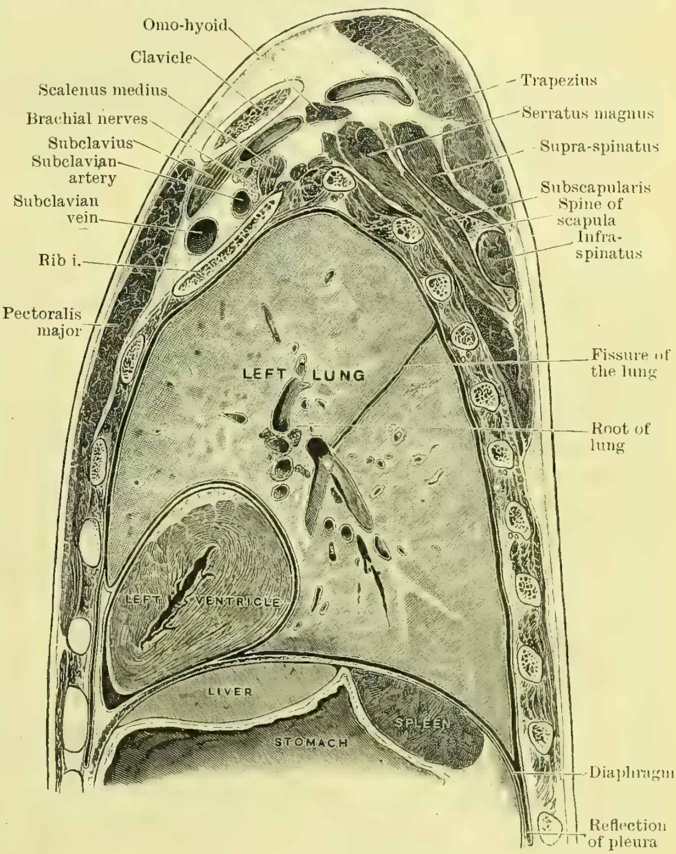


Fig. 635.—Sagittal Section through the Left Shoulder, Lung, and Apex of the Heart.

Fissures and Lobes of the Lungs.—The *left lung* is divided into two lobes by a long deep fissure which penetrates its substance to within a short distance of the hilus. Above and below the hilus this fissure cuts right through the lung and appears upon the mediastinal or inner surface. Viewed from the outer aspect of the organ, it begins at the posterior border about two and a-half inches below the summit of the apex, about the level of the vertebral end of the third rib, and is continued downwards and forwards in a somewhat spiral direction to the base of the lung, which it reaches a short distance behind its anterior end. The **upper lobe** of the lung (lobus superior) lies above and in front of this cleft. It is conical in form, with an oblique base, and the apex and the whole of the anterior border of the lung belong to it. The **lower lobe** (lobus inferior) lies below and behind the fissure. It is the more bulky of the two, and includes almost the entire base and the greater part of the thick posterior border.

In the *right lung* there are two fissures subdividing it into three lobes. One of these fissures is very similar in its position and relations to the fissure in the left lung. It is, however, rather more vertical in its direction, and ends below somewhat further outwards. It separates the lower lobe from the upper and middle lobes. The second cleft begins in the main fissure at the posterior border of the lung, and proceeds horizontally forwards, to end at the anterior border of the lung at the level of the fourth costal cartilage. The **middle** or **intermediate lobe** of the right lung is triangular or wedge-shaped in outline.

Variations.—Variations in the pulmonary fissures are fairly common. Thus it sometimes happens that the middle lobe of the right lung is imperfectly cut off from the upper lobe. Supernumerary fissures also are not infrequent, and in this way the left lung may be cut into three lobes, and the right lung into four or even more lobes. The occurrence of a **lobus azygos** in the right lung is a variation of some interest, seeing that such a lobe is constant in certain mammals. It is a small accessory lobe, pyramidal in form, which makes its appearance on the lower part of the inner aspect of the right lung. In certain cases the vena azygos major is enclosed within a fold of pleura, and is sunk so deeply in the pulmonary substance of the right lung that it marks off a small accessory lobe.

ROOT OF THE LUNG.

The term **root of the lung** (radix pulmonis) is applied to a number of structures which enter and leave the lung at the hilus on its inner surface. They are held together by an investment of pleura, and constitute a pedicle which attaches the lung to the mediastinal wall of the pleural cavity. The phrenic nerve descends a short distance in front of the pulmonary root, whilst the vagus nerve breaks up into the posterior pulmonary plexus on its posterior aspect under cover of the investing pleura. The delicate anterior pulmonary plexus is placed in front of the root of the lung beneath the pleura, whilst from the lower border of the root of the lung the ligamentum latum pulmonis extends downwards. . These are the relations which are common to the pulmonary root on both sides of the body, but there are others which are peculiar to each side. On the *right side* the superior vena cava lies in front of the pulmonary root, whilst the vena azygos major arches over its upper aspect. On the *left side* the aorta arches over the root of the lung, whilst the descending thoracic aorta passes down behind it.

Constituent Parts of the Pulmonary Root.—The most important structures which enter into the formation of the pulmonary root are (1) the two pulmonary veins; (2) the pulmonary artery; (3) the bronchus. But in addition to these there are one or more small bronchial arteries and veins, the pulmonary nerves and the pulmonary lymphatic vessels, and some bronchial glands.

The **pulmonary nerves** come from the vagus nerve and also from the sympathetic system. They enter the lung and follow the air-tubes through the organ. The **bronchial arteries** are small vessels which carry blood for the supply of the lung tissue. They arise from the aorta or from an intercostal artery, and vary in number from one to three for each lung. In the root of the lung they lie on the posterior aspect of the bronchus, and they follow the air-tubes through the organ. Part of the blood conveyed to the lung by the bronchial arteries is returned by the pulmonary veins; the remainder is returned by special **bronchial veins** which open on the right side into the vena azygos major, and on the left side into the vena azygos minor superior.

The **lymphatic vessels** of the lung, as they emerge from the hilus, unite into a small number of trunks, which, placed behind the large pulmonary vessels, open into the bronchial glands.

The **bronchus** in the root of the lung lies behind the great pulmonary vessels. The **pulmonary artery** occupies a different position on the two sides in relation to the main or undivided part of the bronchus. On the right side it is placed below it, whilst on the left side it crosses the bronchus and occupies a higher level in the pulmonary root. The two **pulmonary veins** on both sides lie at a lower level in the root of the lung than the pulmonary artery and bronchus, whilst the upper of the two veins occupies a plane in front of the pulmonary artery (Fig. 632, p. 934).

Distribution of the Bronchial Tubes within the Lungs.—The two lungs are not symmetrical; the right lung is subdivided into three lobes, and the left lung is cleft into two lobes. The bronchi exhibit a corresponding want of symmetry. The *right bronchus*, as it approaches the pulmonary hilus, gives off two branches for the upper and middle lobes of the right lung respectively, and then the main stem of the tube enters the lower lobe. The *left bronchus* sends off a large branch to the upper lobe of the left lung, and then sinks into the lower lobe. The first branch of the right bronchus for the upper right pulmonary lobe leaves the main stem about one inch from the trachea. The first branch of the left bronchus, on the other hand, takes origin about twice that distance from the trachea.

The relation of the pulmonary artery to the bronchial subdivisions is different on the two sides. On the right side it turns backwards to reach the posterior aspect of the bronchus below the first and above the second bronchial branch. On the left side the pulmonary artery turns backwards above the level of the first bronchial branch. On the right side, therefore, the first bronchial branch is placed above the pulmonary artery, and in consequence it is termed the **eparterial bronchus**; all the others lie below the artery, and are termed **hyparterial bronchi.** On the left side there is no eparterial branch; they are all hyparterial.

When the main stem of the bronchus is followed into the inferior lobe of each lung, it is seen to travel downwards and backwards in the pulmonary substance until it reaches the thin back part of the base of the lung which lies between the diaphragm and the thoracic wall, and there it ends. As it proceeds through the inferior lobe it gives off a series of large **ventral** and a series of smaller **dorsal branches.** As a rule these are three in number in each case, and the dorsal and ventral branches do not arise opposite to each other, but alternately, one from the back, and then another, after a slight interval, from the front of the tube. The first hyparterial division on each side (*i.e.* the branch to the middle lobe of the right lung and the branch to the upper lobe of the left side) is generally regarded as the first member of the ventral group.

It was Aeby who first recognised the existence in each lung of a main or stem bronchus giving off a ventral and dorsal series of branches, and who drew the distinction between the eparterial and hyparterial bronchial branches. A consideration of these relations led this author to conclude that the eparterial bronchus and the upper lobe of the right lung have no morphological equivalents on the left side of the body. In other words, he was led to believe that the middle lobe of the right lung is the homologue of the upper lobe of the left lung. Hasse, who has also investigated the subject, endorses this view, with certain modifications and additions, and the hypothesis, either in its original state as presented by Aeby, or as subsequently modified by Hasse, has been very generally accepted by anatomists. More recent research, however, has seriously affected the stability of this conclusion. Narath contends that the distinction between the eparterial bronchus of the right side and the hyparterial bronchi of both sides is not one of fundamental importance, and further, that a branch which arises from the first hyparterial bronchus on the left side and turns upwards into the apex of the left lung is the direct equivalent of the eparterial bronchus of the right side. This he terms the **apical bronchus,** and he believes that it represents the first dorsal branch of the left stem bronchus. Huntington, in a very convincing paper, strongly supports the contention of Narath, and holds that, except "for purposes of topography, we should abandon the distinction between eparterial and hyparterial bronchi." With Narath he regards the eparterial bronchus as a secondary branch which has migrated in an upward direction on the main stem. According to Huntington, therefore, Aeby's proposition should be amended as follows:—

Right side.				**Left side.**
Upper	+	middle lobe	=	Upper lobe.
Lower	+	cardiac lobe	=	Lower lobe.

The cardiac lobe mentioned in this table is the occasional azygos lobe to which reference has already been made, and it is interesting to note that, whilst the lobe in question as a separate entity is rarely seen in the human lung, the bronchus which corresponds to it is always

present in the pulmonary substance as an accessory branch, which proceeds from the main stem as it traverses the lower lobe of the right side. It receives the name of the **cardiac bronchus.**

Structure of the Lung.

The lung is constructed so that the blood which enters it through the pulmonary artery is brought into the most intimate relation with the air which enters it through the trachea and bronchi. An interchange of materials between the blood and the air is thus rendered possible, and the object of respiration is attained. As a result of this interchange the dark impure blood which flows into the lung through the pulmonary artery is rendered bright red and arterial.

Lobules of the Lung.—A thin layer of subpleural connective tissue lies subjacent to the continuous coating which the lung receives from the visceral pleura. From the deep surface of this subpleural layer fine septal processes penetrate into the substance of the lung, and these, with the connective tissue which enters at the hilus upon the vessels and bronchi, constitute a supporting framework for the organ. The lung is lobular, and on the surface the small polygonal areas which represent the lobules are indicated by the pigment present in the connective tissue septa which intervene between them. Although no pigment is present, the lobular character of the lung is particularly well marked in the fœtus, and with a little care the surface lobules in the fœtal lung can be separated from each other by gently tearing through the intervening connective tissue. The lobules thus isolated are pyriform or pyramidal in form. The broad bases of these lobules abut against the subpleural layer, whilst each of the deep narrow ends receives a minute division from the bronchial system of tubes. The lobules which lie more deeply in the substance of the organ are not so large, and are irregularly polygonal in form.

Alveolar Ducts, Infundibula, and Air-cells.—The larger branches of the bronchi, as they traverse the lung, give off numerous divisions which, by repeated branching, ultimately form a system of tubes which pervade the entire organ. At first the bronchial divisions come off at very acute angles, but as the finer ramifications are reached this character becomes much less apparent. There is no anastomosis between the bronchial branches.

Within the various lobules the finer bronchioles send off further branches, which proceed at right angles from them. Soon the ultimate tubes are reached. These are not cylindrical, but have their walls pouched out by numerous hemispherical diverticula. Such a bronchiole is called an **alveolar duct**, and the diverticula are the **air-cells** or **alveoli.** Finally the alveolar duct divides into two, three, or more terminal parts, which become expanded and form the club-shaped, blind terminations of the bronchial system of tubes. These cæcal endings are the **infundibula**, and the walls of each are thickly covered by alveoli or air-cells, all of which open into the infundibulum as into a corridor.

Structure of the Bronchi.—When the large bronchi enter the lung they become cylindrical, and lose the flattening on the posterior aspect which is characteristic of the primary bronchi outside the lung. They possess the same coats as are present in the case of the trachea and primary bronchi, but as the tubes become smaller by repeated division, these coats become correspondingly thinner and finer. Certain marked differences also in the manner in which the constituents of these coats are arranged become apparent.

In the **external fibro-cartilaginous coat** the cartilage is no longer present in the form of incomplete rings, but in irregular plates or flakes deposited at various points around the wall. As the tubes diminish these cartilaginous deposits show a corresponding reduction in size, until at last, in bronchi of 1 mm. in diameter, they disappear altogether. The **glands** in relation to the tubes for the most part cease to exist about the same point. The **muscular** or **middle coat**, which in the trachea and primary bronchi is confined to the back wall of the tube, forms a continuous layer of circularly-arranged bundles in the bronchi as they ramify within the lung. Spasmodic contraction of the muscular coat gives rise to the serious symptoms which accompany asthmatic affections. The muscular fibres of the middle coat may be traced as far as the infundibula, on the walls of which they are present in considerable numbers. The **mucous lining** of the tubes becomes greatly thinned as it is followed into the smaller bronchioles. It contains a large number of longitudinally-arranged elastic fibres, and is disposed in longitudinal folds, so that when the tube is cut across the lumen presents a stellate appearance. The mucous membrane is lined by ciliated columnar epithelium.

Structure of the Infundibula and Alveoli.—The walls of the infundibula and alveoli are exceedingly fine and delicate, but nevertheless constituents continuous with those observed in the three coats of a bronchus are found entering into their construction. The epithelium is reduced to a single layer. Further, it is no longer columnar and

ciliated, but it has become flat and pavement-like. Two kinds of epithelial cells may be recognised—(1) a few small granular polygonal cells, arranged singly or in groups of two or three; (2) more numerous thin cells of large size, and somewhat irregular in outline. Outside the epithelium is a delicate layer of faintly-fibrillated connective tissue. This is strengthened by a network of elastic fibres which is specially well marked around the mouths of the alveoli, and is also to some extent carried over the walls of the air-cells. Muscular fibres are likewise present on the walls of the infundibula, but it is questionable if any are prolonged over the air-cells.

Pulmonary Vessels.—The pulmonary artery, as it traverses the lung, divides with the bronchi, and closely accompanies these tubes. The resultant branches do not anastomose, and for the most part they lie above and behind the corresponding bronchi. The fine terminal divisions of the artery join a dense capillary plexus which is spread over the alveoli or air-cells. This vascular network is so close that the meshes are barely wider than the capillaries which form them. In the partitions between adjacent alveoli there is only one layer of the capillary network, and thus the blood flowing through these vessels is exposed on both aspects to the action of the air in the air-cells. The radicles of the pulmonary vein arise in, and carry the blood from, the pulmonary capillary plexus. Each afferent arteriole supplies the blood which flows through the capillaries spread over a number of neighbouring alveoli, and in like manner each efferent venous radicle drains an area corresponding to several adjoining air-cells. At first the veins run apart from the arteries, but after they have attained a certain size they join them and the bronchi. As a rule the pulmonary veins are placed on the lower and front aspect of the corresponding bronchi.

Development of the Respiratory Apparatus.

The larynx, the trachea, the bronchi, and the lungs arise as an outgrowth from the ventral aspect of the foregut. The first indication of a respiratory tract occurs in the human embryo when it has attained a length of 3·2 mm., on or about the fifteenth day of development. A median longitudinal groove makes its appearance within the foregut on its ventral wall. This extends from the pharynx in front to the region of the stomach behind, and it gradually deepens as it passes backwards. The hinder or gastric end of this groove ends in a blind diverticulum or pocket, which freely communicates with the cavity of the foregut, and forms a hollow median protrusion on the ventral aspect of this portion of the primitive alimentary canal. Further, it is lined with entoderm or hypoblast continuous with the entodermal lining of the foregut.

Trachea and Larynx.—The groove on the ventral aspect of the foregut becomes first partially and then completely separated from the part of the foregut which lies on its dorsal aspect by two lateral ridges which grow inwards and finally meet. Two tubes are thus formed—viz. one behind, the œsophagus, and the other in front, the trachea and larynx. At their cephalic ends a communication between the two tubes is preserved as the permanent communication between the larynx and pharynx.

The cephalic end of the air-tube, which is thus separated off from the foregut, becomes enlarged to form the larynx, whilst the remainder is developed into the trachea. The cartilages of the larynx do not make their appearance until the eighth or ninth week. The thyroid cartilage is believed to be formed out of the ventral portions of the cartilages which support the 4th and 5th visceral arches of the two sides united in the median plane. The epiglottis takes form in the upper or front part of the furcula (see chapter on Embryology, p. 33), whilst the arytenoids are developed in its lower or back part. The cricoid cartilage and the tracheal rings are formed in the mesoderm of the air-tube.

Lungs and Bronchi.—The entodermic diverticulum, or pocket in which the gastric end of the primitive respiratory groove terminates, very early bifurcates into two vesicular portions, which represent the primitive right and left bronchi and lungs. From the first the right pulmonary vesicle is slightly the larger of the two. Both elongate, and almost immediately each part undergoes a subdivision—the right into three vesicles, and the left into two vesicles—thus early indicating the three lobes of the right lung and the two lobes of the left lung. The hypoblastic or entodermal subdivisions thus formed are surrounded by mesoderm. The main subdivisions continue to branch and rebranch, pushing their way into the pulmonary mesoblast, until the complete bronchial tree is formed. The method of subdivision is very characteristic, and from the first the various branches are bulbous or flask-shaped at their extremities. These bifurcate, and although at first the two subdivisions in each case appear of equal importance, one grows out as the continuation of the main bronchial stem, whilst the other remains as a lateral branch.

When the ramification of the entodermal tubes into the lung mesoderm is complete, the small terminal flask-shaped extremities of the various branches represent the infundibula. At first these are devoid of air-cells, but between the sixth month and the termination of gestation the alveolar diverticula make their appearance on the alveolar ducts and on the infundibula. It is thus seen that the epithelial lining of the entire system of bronchial tubes, infundibula and alveoli, is originally derived from the entodermal lining of the fore-gut. The other constituents which enter into the constitution of the lungs and bronchi are derived from the mesoblast.

The rudiments of the lungs grow backwards on either side of the œsophagus into the fissure-like portion of the cœlom which occupies the thoracic region. They push before them the epithelial lining of the latter, and thus acquire their covering of visceral pleura. By the development of the diaphragm and the pericardium the pleural portions of the cœlom become cut off from the peritoneal cavity and from each other. Our knowledge of the development of the lungs has been greatly extended by the writings of Professor His and Professor Arthur Robinson.

THE DIGESTIVE SYSTEM.

BY AMBROSE BIRMINGHAM.

UNDER this head will be described the parts which are connected with the reception and mastication of the food, and its digestion and passage through the body. As the greater part of the digestive system is placed within the abdomen, the description of this cavity as a whole, with that of its lining membrane the peritoneum, will be included.

The different parts of the digestive system may be grouped under the following heads, viz. :—

1. The Alimentary Canal or Digestive Tube.
2. The Digestive Glands.
3. Accessory Parts.

Alimentary Canal.—The alimentary canal, taken as a whole, measures about 30 feet in length (Fig. 636), and consists of the following parts in order :—mouth, pharynx, œsophagus, stomach, small and large intestines. The **mouth** is the first division of the tube. It is separated from the nasal cavities above by the **palate**, and opens behind into the **pharynx**. This latter is an expanded portion of the canal lying behind both the mouth and the nasal cavity, the former opening into it through the **isthmus of the fauces**, the latter through the **posterior nares**; whilst lower down, close to the base of the tongue, the aperture of the larynx is found on its anterior wall. Opposite the lower border of the larynx, the pharynx is succeeded by the **œsophagus**, a long and comparatively straight portion of the digestive tube, leading through the neck and thorax to the abdomen, which it reaches by piercing the diaphragm. Immediately after entering the abdomen the tube expands into a pear-shaped dilatation, the **stomach**. This is followed by over 20 feet of **small intestine**, the junction of the two being marked by a constriction, the **pylorus**. The small intestine presents three more or less arbitrary divisions—namely, (*a*) the **duodenum**, a part about 10 inches in length, and curved somewhat like a horse-shoe, which is closely united to the posterior abdominal wall ; (*b*) the **jejunum**, which includes the upper two-fifths, and (*c*) the **ileum**, the lower three-fifths of the small intestine beyond the duodenum. The jejunum and ileum are movably suspended from the posterior abdominal wall by the **mesentery**, a fan-shaped fold of the **peritoneum** or lining membrane of the abdominal cavity. The terminal part of the ileum opens into the side of the **large intestine**, a few inches ($2\frac{1}{2}$) from the extremity of the latter. There is thus formed a cul-de-sac, the **cæcum**, in connexion with which is found a small worm-shaped protrusion, the **vermiform appendix**.

The orifice through which the ileum opens into the large intestine is guarded by the **ileo-cæcal valve**, which prevents any return of its contents from the large into the small bowel. After the cæcum comes the **ascending colon**, which runs up in the right side of the abdomen. This is succeeded in order by the **transverse colon** crossing from right to left, the **descending colon** running down on the left side, the **sigmoid flexure** of the colon (which includes the iliac and greater part of the pelvic colons of the text), and finally the **rectum**, which opens on the surface at the **anus**.

Digestive Glands.—Whilst the greater part of the alimentary canal is furnished with numerous minute glands contained entirely within its walls,

there are in addition certain special accumulations of glandular tissue, namely, the **liver**, the **pancreas**, and the **salivary glands**, which, although developed in the

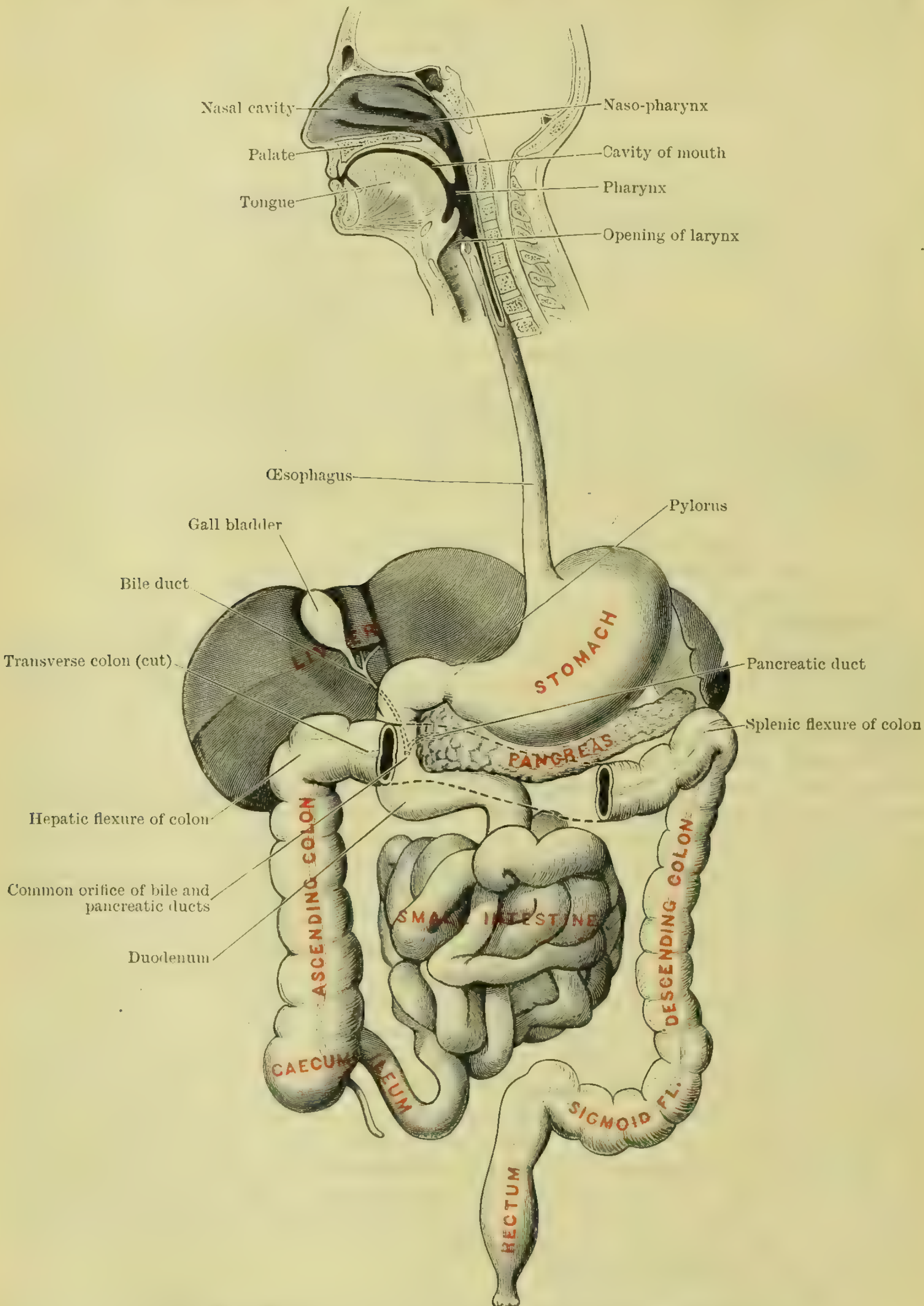


Fig. 636.—General View of the Digestive System (diagrammatic).

The transverse colon has been cut to show the duodenum, but its course is indicated by dotted lines. The vermiform appendix is seen hanging down from the cæcum. The loop of large intestine which precedes the rectum is marked "sigmoid flexure," and includes the iliac colon and the greater part of the pelvic colon.

embryo as outgrowths of its wall, lie entirely outside the tube in the adult, and are connected with it by special ducts through which the gland-secretions pass. The largest of these, the **liver**, is placed in the upper and right portion of

the abdominal cavity, immediately beneath the diaphragm, and its secretion—the bile—is conveyed into the duodenum by the **bile duct.** The **pancreas,** next in size, lies across the front of the vertebral column, with its right end or head resting in the concavity of the duodenum, into which its secretion flows through the **pancreatic duct.** The **salivary glands,** of which there are three chief pairs—**parotid, submaxillary,** and **sublingual**—are placed about the face, and their ducts, which convey the saliva, open into the mouth. Whilst the secretion of these latter undoubtedly possesses some digestive action, and they must consequently be classed as digestive glands, nevertheless the saliva is to be looked upon as a mechanical lubricant, which facilitates swallowing and the movements of the tongue in speaking and masticating, rather than as an aid to the digestive process.

Accessory Parts.—Under this heading we group the teeth, tongue, gums, palate, and tonsils. The **teeth,** 32 in number in the adult, are embedded in the jaws and surrounded by the **gums.** The **tongue** is a muscular organ, useful alike in masticating, swallowing, speaking, and in the exercise of the sense of taste, which specially resides in its modified epithelium; it occupies the greater portion of the floor of the mouth, whilst the roof of that cavity is formed by the **hard palate** anteriorly, and by the **soft palate** behind. Finally, the **tonsils** (Fig. 638) are two large masses of lymphoid tissue, found on the side-walls of the oral portion of the pharynx, just behind the mouth.

THE MOUTH.

The mouth is the expanded upper portion of the digestive tube, specially modified for the reception and mastication of the food. In it we distinguish: the **aperture of the mouth** placed between the lips; the **vestibule,** the slit-like space which intervenes between the teeth and gums internally, and the lips and cheeks externally (Fig. 637); and the **cavity of the mouth,** which lies within the round of the dental arches, and opens behind into the pharynx through the **isthmus of the fauces** (Fig. 638).

The **aperture of the mouth** (rima oris) is the upper or anterior opening of the alimentary canal, and is bounded above and below by the corresponding lips, which, by their junction at the sides, form the angles of the mouth (commissuræ labiorum). In a state of rest, with the lips in apposition, the rima appears as a slightly curved line, corresponding in length to the interval between the first premolar teeth, and in level to a line drawn across just below the middle of the upper incisor crowns. The shape of the rima varies with every movement of the lips, from the resting linear form, curved like the conventional bow, to a circular or oval shape when the mouth is widely open, or the "pursed up" condition produced by the contraction of the orbicularis oris.

The **vestibule** (vestibulum oris, Fig. 637) lies immediately within the aperture of the mouth. In the normal resting condition its cavity is practically obliterated by the meeting of its walls, which reduces it to a slit-like space. It is limited on the one hand by the deep surface of the lips and cheeks, and on the other by the dental arches and gums. Its narrow roof and floor are formed respectively by the reflection of the mucous membrane, from the deep surface of the lips and cheeks to the corresponding gum. This reflection is interrupted in the middle line by a small but prominent fold of the mucous membrane, the **frenulum,** which connects the back of each lip to the front of the gum. The upper frenulum is the better developed, and is readily brought into view by everting the lip.

On the outer wall of the vestibule, opposite the crown of the middle upper molar, is seen, upon a variably developed eminence (Fig. 647), the small opening of Stenson's duct, which conveys the saliva from the parotid gland to the mouth.

When the teeth are in contact the vestibule communicates with the cavity of the mouth, only through the small and irregular spaces left between the opposing teeth, and posteriorly by a wider but variable aperture behind the last molars.

Advantage is sometimes taken of the presence of this aperture, which lies between the wisdom teeth and the ramus of the jaw, for the introduction of liquid food in certain cases—trismus, anchylosis, etc.—in which the mouth is rigidly closed.

The anterior border of the masseter can be distinctly felt with the finger, on the outer wall of the vestibule, when the muscle is thrown into a state of contraction. Still further back, the front of the coronoid process, bearing the lower part of the insertion of the temporal muscle, can be easily made out. Whilst the pterygo-maxillary ligament, which corresponds to, and is felt along with, the anterior border of the internal pterygoid, is distinguishable as a pliant ridge when the finger is carried from the front of the coronoid process inwards behind the wisdom teeth to the cavity of the mouth.

In addition to Stenson's duct, the ducts of numerous small glands which are embedded in the lips and cheeks open into the vestibule.

Under normal conditions, as pointed out above, the lips and cheeks lie against the teeth and gums, obliterating the cavity of the vestibule, and helping, with the aid of the tongue, to keep the food between the grinding surfaces of the molar teeth during mastication. In facial palsy, however, owing to the paralysis of their muscles, the lips and cheeks fall away from the dental arches, and allow the food to pass out from between the teeth and to accumulate in the vestibule.

Lips (labia oris, Fig. 639).—These are the two movable folds, covered superficially by skin, and on their deep surface by mucous membrane, which surround the rima oris. Laterally the two meet at the angles of the mouth, and beyond this are

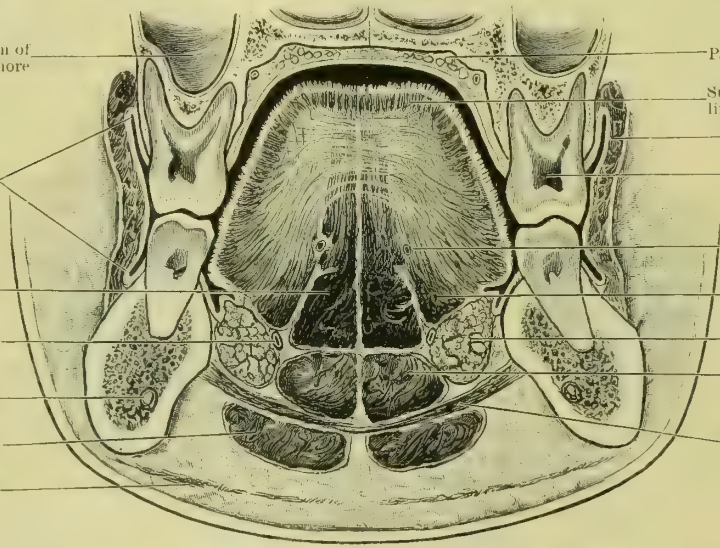


FIG. 637.—CORONAL SECTION THROUGH THE CLOSED MOUTH.

The slit-like character of the vestibule, the manner in which the tongue fills up the mouth cavity, the close apposition of the teeth, the relations of the roots of the upper molars to the antrum of Highmore, the plica sublingualis over the sublingual gland, and the position of the ranine artery should be noted.

prolonged into the cheeks, with which they are continuous. The upper lip presents on its superficial surface a well-marked vertical groove, the **philtrum**, bounded by two distinct ridges descending from the columella nasi (Fig. 643); inferiorly the groove widens out, and terminates opposite a slight projection—the *labial tubercle*—on the free edge of the upper lip. This tubercle is particularly well developed in children, and is chiefly responsible for the characteristic curve of the rima oris. The lower is usually longer and more movable than the upper lip.

In passing from before backwards the following structures are found in the lips:—(1) The **skin**, which is closely beset with hairs, small and fine in the child and female, long and stout in the adult male. (2) A layer of fatty **superficial fascia** continuous with the fascia of the face generally. (3) The **orbicularis oris muscle**, continuous at its periphery with the various muscles converging towards the mouth. A number of its fibres, or those of the muscles joining it, pass through the superficial fascia and are attached to the skin, thus establishing a close connexion between the latter and the muscle. (4) The **submucous tissue**, which is occupied by an almost continuous layer of racemose glands—the **labial glands** (glandulæ labiales). These open into the vestibule, and their secretion is said to be mucous. (5) The **mucous membrane** of the mouth, covered by stratified squamous epithelium. Between the orbicularis and mucous membrane, but nearer to the

former, that is, in the deeper part of the submucosa, the coronary artery is found a short distance from the free margin of the lip, running to meet its fellow of the opposite side.

The free margin of the lip is covered by a dry and otherwise modified mucous membrane. It begins where the integument changes colour at the outer edge of the lip, and ends posteriorly just behind the line along which the two lips meet when closed, where it passes into the ordinary moist mucous membrane of the vestibule. It presents numerous simple vascular papillæ, and its nerves (which are derived from the infra-orbital in the upper lip, from the long buccal at the angles, and from the mental branch of the inferior dental in the lower lip) terminate in special end organs, hence the acute sensitiveness of this part. In the child, at birth, the margin of the lip is divided by a very pronounced groove or fissure into an outer and an inner zone, differing considerably in their appearance.

When the tongue is pressed firmly against the back of the lips and moved about, the labial glands can be distinctly felt through the mucous membrane, giving the impression of a knobby or irregular surface. The glands, which are about the size of hemp-seeds and can be readily displayed by removing the mucous membrane, are more numerous in the lower than in the upper lip. Stoppage of their ducts, with the resulting distension of the glands, gives rise to "mucous cysts," a well-known pathological condition.

It should be remembered, in connexion with epithelioma of this part, that the lymphatics of both lips pass down to join the submaxillary lymphatic glands.

Cheeks (buccæ).—The cheeks resemble the lips in structure, being formed of corresponding layers. Superficially is the skin. Under this lies the fatty superficial fascia of the face, through which Stenson's duct runs inwards to pierce the buccinator; in it also, near the end of the duct, are found four or five mucous glands, as large as hemp-seeds. These are known as the **molar glands** (glandulæ molares); their ducts pierce the cheek and open into the vestibule. Beneath this superficial fascia lies the buccinator muscle, covered by the thin bucco-pharyngeal aponeurosis. Deeper still is the submucosa, which, like that of the lips, contains numerous racemose **buccal glands** (glandulæ buccales). And finally the mucous membrane is reached (Fig. 640).

An important constituent of the cheek of the infant is the **sucking pad** (corpus adiposum buccæ), an encapsuled mass of fat, distinct from the surrounding superficial fascia, which lies on the outer side of the buccinator, and passes backwards into the large recess between that muscle and the overlying anterior part of the masseter. This fatty mass, which is relatively more developed in the child than in the adult, strengthens the cheek, and helps it to resist the effects of atmospheric pressure during the act of sucking. In the adult the remains of the pad can be distinctly made out under the anterior border of the masseter.

Cavity of the Mouth Proper (cavum oris proprium).—This is the space situated within the dental arches, which latter, with the gums, separate it from the vestibule (Fig. 637), so that the two communicate, when the teeth are in contact, only by the irregular interdental spaces, and through the passages behind the wisdom teeth already referred to.

Posteriorly it opens, through the isthmus of the fauces, into the pharynx (Fig. 638).

Its **roof** is formed by the hard and the greater part of the soft palate; whilst its **floor**, in the ordinary resting condition, is entirely occupied by the tongue (Fig. 640). If, however, the tip and marginal parts of the tongue be raised, there is exposed a limited surface to which the term "floor of the mouth" or sublingual region is more usually applied (Fig. 643).

The **sublingual region** (Fig. 643) is covered by the oral mucous membrane which is carried across from the deep surface of the gum to the inferior aspect of the tongue, with the mucous membrane of which it becomes continuous. When the tip of the tongue is raised the membrane forms in the middle line a prominent fold, the **frenum linguæ**, stretching from the floor of the mouth to the under surface of the tongue. On each side of the frenum, near its junction with the floor, there can be readily made out a prominent soft papilla (caruncula sublingualis), on which the opening of **Wharton's duct** (of the submaxillary gland) may be seen (Fig. 643). Running outwards and backwards on each side from this, and occupying the greater part of the floor of the mouth, there is a well-marked ridge (plica sublingualis) due to the projection of the underlying sublingual gland, most of the ducts of which open near the crest of the ridge.

When the mouth is closed, and respiration is carried on through the nose, the cavum oris is reduced to a slit-like space, and practically obliterated by the tongue coming in contact with the palate above, and with the gums and teeth laterally and in front (Fig. 637). When the mouth is slightly open and the teeth nearly in contact, the tongue becomes somewhat concave or grooved along the middle line, and leaves a channel-like space between it and the palate, while it remains in contact with the roof and gums laterally. By depressing the hyoid bone with the root of the tongue, the cavum oris can be increased to a considerable size even when the teeth are in contact. Finally, by the simultaneous descent of the lower jaw and hyoid bone with the tongue, and the ascent of the soft palate, the cavity is increased to its greatest dimensions (Fig. 638).

Gums (gingivæ).—This term is applied to the red firm tissue, continuous with the mucous membrane of the vestibule on the one hand, and with that of the palate or floor of the mouth on the other (Fig. 637), which covers the alveolar borders of the maxilla and mandible, and surrounds the necks of the teeth. The gums are composed of dense fibrous tissue, inseparably united to the periosteum and covered by mucous membrane. They are richly supplied with blood-vessels, but sparsely with nerves, and are covered by stratified squamous epithelium. Around the neck—or more correctly the base of the crown—of each tooth, the gum forms a free overlapping collar, and at this part particularly it is closely beset with small papillæ, visible to the naked eye. In thickness it usually measures from 1 to 2 mm.

THE PALATE AND ISTHMUS FAUCIUM.

The **palate** (palatum) is the term applied to the strongly-arched structure which forms the roof of the mouth, and projects posteriorly into the pharynx as a pliant fold, imperfectly dividing that cavity into two (Figs. 639 and 641). Its anterior half or more has a foundation of bone, and separates the nasal fossæ from the mouth. This part is known as the **hard palate**. The posterior portion, which is free from bone, separates the naso-pharynx above, from the mouth and oral pharynx below, and is known as the **soft palate**.

The **hard palate** (palatum durum, Fig. 639) occupies the space within the upper dental arch, and is continuous with the gums in front and laterally, whilst behind it passes into the soft palate. It is formed by the palate processes of the superior maxillary and palate bones (Fig. 652), covered by periosteum, and by a layer of firm mucous membrane. Beneath this mucous membrane, particularly at the sides and in front, is found a considerable quantity of dense fibrous tissue, firmly united to the periosteum on the one hand and to the mucous membrane on the other. This dense tissue forms an effective protection for the palate, and, in addition to the palatine vessels and nerves, it contains in its posterior half a large number of racemose (palatine) glands.

Traversing the middle of the palate is seen a faint central ridge or **raphe** (Fig. 638), indicating its original development from two lateral halves. Behind, this raphe is continued along the soft palate to the base of the uvula, and in front it ends in a slight elevation, the **incisive pad** or papilla palatina. From the anterior end of the raphe a series of transverse ridges of mucous membrane, about six in number, run outwards, just behind the incisor teeth; they are known as the **palatine rugæ**, and are composed of dense fibrous tissue. Sometimes a small pit, which will admit the point of a pin, is seen on each side immediately behind the central incisor teeth, and about 2 mm. from the middle line. These pits correspond to the lower openings of Stenson's canals, with which they are occasionally continuous.

The **soft palate** (palatum molle, or velum pendulum palati, Fig. 639) is a movable valve-like fold which runs obliquely downwards and backwards, like the "tongue" of a whistle, across the cavity of the pharynx almost as far as its posterior wall. Whilst it is attached to the hard palate in front, and blends with the pharyngeal walls laterally, its posterior border is free, and between it and the posterior wall of the pharynx is left a valvular passage—the isthmus of the pharynx—through which the naso-pharynx and the oral pharynx communicate with one another.

The soft palate is composed of two layers of mucous membrane between which are contained the palatine muscles, vessels, nerves, and connective tissue, the aponeurosis of the palate, and, in addition, a very large number of racemose glands. These glands are arranged in a thick continuous layer on the inferior surface beneath the mucous membrane, and form quite one-half of the mass of the soft palate

generally, whilst in its anterior part, where muscular fibres are wanting, they constitute almost its entire thickness.

Its *upper surface*, which is convex, forms a continuation backwards and downwards of the floor of the nasal fossæ (Fig. 639), and is covered by a prolongation of the nasal mucous membrane—ciliated in its upper half or more. The *under surface* is arched, and prolongs backwards the roof of the mouth, towards the cavity of which it looks. *In front* the soft palate is attached to the posterior edge of the hard palate. *Laterally* it blends with the side wall of the pharynx along a very oblique line as it slopes downwards and backwards (Fig. 639). Its *posterior margin* is thin and free: it presents in the middle line an elongated conical projection, the **uvula** (Fig. 638), and at each side of this a sharp concave edge which, arching out, passes downwards and slightly backwards into the **posterior palatine arch** (posterior pillar of fauces). From the under surface of the soft palate, 7 or 8 mm. further forwards, and near the base of the uvula, spring another pair of ridges, the **anterior palatine arches** (anterior pillars of fauces), which pass downwards and slightly forward to the sides of the tongue (Fig. 638).

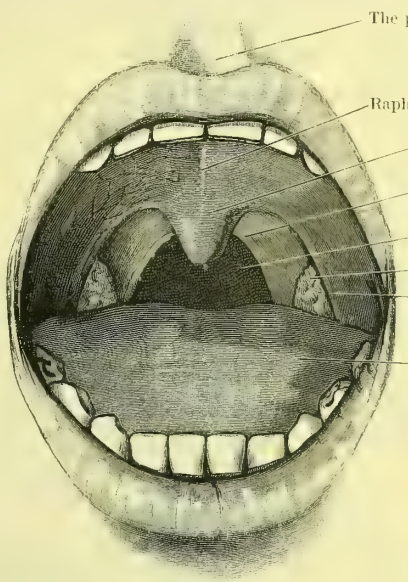


FIG. 638.—OPEN MOUTH SHOWING PALATE AND TONSILS.
It also shows the two palatine arches, and the pharyngeal isthmus through which the naso-pharynx above communicates with the oral portion of the pharynx below.

The anterior part of the soft palate for 8 or 10 mm. ($\frac{1}{3}$ inch) contains practically no muscular fibres; it is composed of the palatine aponeurosis, covered by an extremely thick layer of glands on the under surface and by mucous membrane on both surfaces. This anterior portion is much less movable than the rest of the soft palate, and forms a relatively horizontal continuation backwards of the hard palate, stretching across between the two internal pterygoid plates. It is upon this portion chiefly that the tensor palati acts. The posterior and larger part contains muscular fibres in abundance, slopes strongly downwards, and is freely movable, being the portion upon which the remaining palatine muscles act.

The palatine aponeurosis, which is confined to the anterior part of the soft palate, is in the form of a thin flat sheet, constituting, as it were, a kind of common tendon for the palatine muscles which are attached to (or blended with) its posterior margin; whilst its anterior margin is united to the posterior edge of the palate bone. With the exception of the aponeurosis of the tensor palati which passes into its lateral part, the muscles do not, as a rule, reach further forwards than to within 8 or 10 mm. of the posterior edge of the hard palate.

The **uvula**, already referred to, is a conical projection, very variable in length, which is continued downwards and backwards from the middle of the soft palate. It is composed chiefly of a mass of racemose glands and connective tissue covered by mucous membrane, and containing a slender prolongation of the azygos uvulæ muscle in its upper part.

The **mucous membrane** of the palate, which is covered by stratified squamous epithelium, is firmer and more closely adherent in front, near the rugæ, than behind, near the soft palate.

Mucous glands, the orifices of which can be seen as dots with the naked eye, are extremely abundant in the soft palate, and in the posterior half of the hard palate, except near the raphe. They are wanting in the anterior part of the palate, where the mucous membrane is particularly dense.

The **palatine rugæ** (which correspond to more strongly developed ridges in carnivora, etc.) are very well marked in the child at birth, although, perhaps, relatively less distinct in the fœtus of five or six months; in old age they become more or less obliterated and irregular. At birth, also, and in the fœtus, the incisive pad at the anterior end of the raphe is continued over the edge of the gum into the frenulum of the upper lip.

The **vessels** of the palate are derived from the **posterior palatine artery**, which runs forwards on the hard palate close to the alveolar border, and from the **ascending palatine branch** of the facial, which accompanies the levator palati to the soft palate.

The **nerves**—all branches of Meckel's ganglion—are: the **large posterior palatine**, which descends through the posterior palatine canal and runs forward on the hard palate with the posterior palatine artery; the **naso-palatine**, which passes down through the foramen of Scarpa and reaches the front of the hard palate; and the **small posterior** and **accessory posterior palatine nerves**, which run through the accessory palatine canals and supply the soft palate.

Fauces or **Isthmus of the Fauces** (isthmus faucium).—This is the aperture through which the mouth communicates with the pharynx (Fig. 638). It is bounded at the sides by the anterior palatine arches, above by the under surface of the soft palate, and below by the dorsum of the tongue; in width it corresponds pretty closely to the cavum oris.

The **anterior palatine arches** (arcus glosso-palatinus), often known as the anterior pillars of the fauces, are two prominent folds of mucous membrane, containing the palato-glossus muscles in their interior, which bound the isthmus of the fauces laterally (Fig. 638). Springing above from the under surface of the soft palate, a little way (about 8 mm.) in front of its free edge, and near the base of the uvula, they pass downwards and slightly forwards to join the tongue a little behind the middle of its lateral border.

The **posterior palatine arch** is described with the pharynx (p. 984).

THE TONGUE.

The tongue (lingua) is a large mobile mass composed chiefly of muscular tissue, and covered by mucous membrane, which occupies the floor of the mouth and forms the anterior wall of the oral pharynx (Fig. 639).

Whilst the sense of taste resides chiefly in its modified epithelium, the tongue is also an important organ of speech, and, in addition, it assists in the mastication and deglutition of the food—functions which it is well fitted to perform, owing to its muscular nature and great mobility. In length it measures, when at rest, about three and a half inches, but both its length and width are constantly varying with every change in the condition of the organ, an increase in length being always accompanied by a diminution in width, and *vice versa.*

In describing the tongue we distinguish the following parts: the **body** (corpus linguæ), made up chiefly of striped muscle, and forming the mass of the organ; the **dorsum** (Fig. 640), which looks towards the palate and pharynx, and is free in its whole extent; the **base**, the posterior wide end which is attached to the hyoid bone; the **apex** or tip, the pointed and free anterior extremity; the **margin**, which is free in its anterior half or more, *i.e.* in front of the attachment of the anterior palatine arch (Fig. 640). Finally, the unattached portion on the inferior aspect, seen when the apex is turned strongly upwards (Fig. 643), constitutes the **inferior surface**; whilst the attached portion, fixed by muscles and mucous membrane to the hyoid bone and mandible, is known as the **root**.

The **dorsum of the tongue** (dorsum linguæ), when the organ is at rest, is strongly arched from before backwards in its whole length (Fig. 639), the greatest convexity corresponding to the attachment of the anterior palatine folds. When removed from the body the tongue, unless previously hardened *in situ,* loses its natural shape, and appears as a flat, elongated oval structure, which gives a very erroneous idea of its true form and connexions.

Corresponding to its differently-directed portions, the dorsum is naturally divided into two areas—an anterior or *oral part,* which lies nearly horizontally on the floor of the mouth, and constitutes about two-thirds of the length of the whole tongue (Fig. 640); and a posterior or *pharyngeal part,* the remaining third of the organ, which is placed nearly vertically, and forms the anterior wall of the oral pharynx (Fig. 641). The separation between these two parts, which differ in appearance as well as in direction, is indicated by a distinct V-shaped groove, called the **sulcus terminalis** (Fig. 641), the apex of which is directed backwards, and corresponds to a blind depression on the surface of the tongue, the **foramen cæcum,** whilst its diverging limbs pass outwards and forwards towards the attachments of

the anterior palatine arches. The foramen cæcum is the remains of a tubular down-growth formed early in embryonic life, in the region of the dorsum of the tongue, from which the isthmus of the thyroid gland is developed (see page 36).

The **posterior or pharyngeal portion of the dorsum linguæ** (Fig. 639), nearly vertical in direction, forms the greater portion of the anterior wall of the oral pharynx (Fig. 641). Its surface is free from evident papillæ, but is thickly studded with rounded projections, each presenting, as a rule, a little pit, visible to the

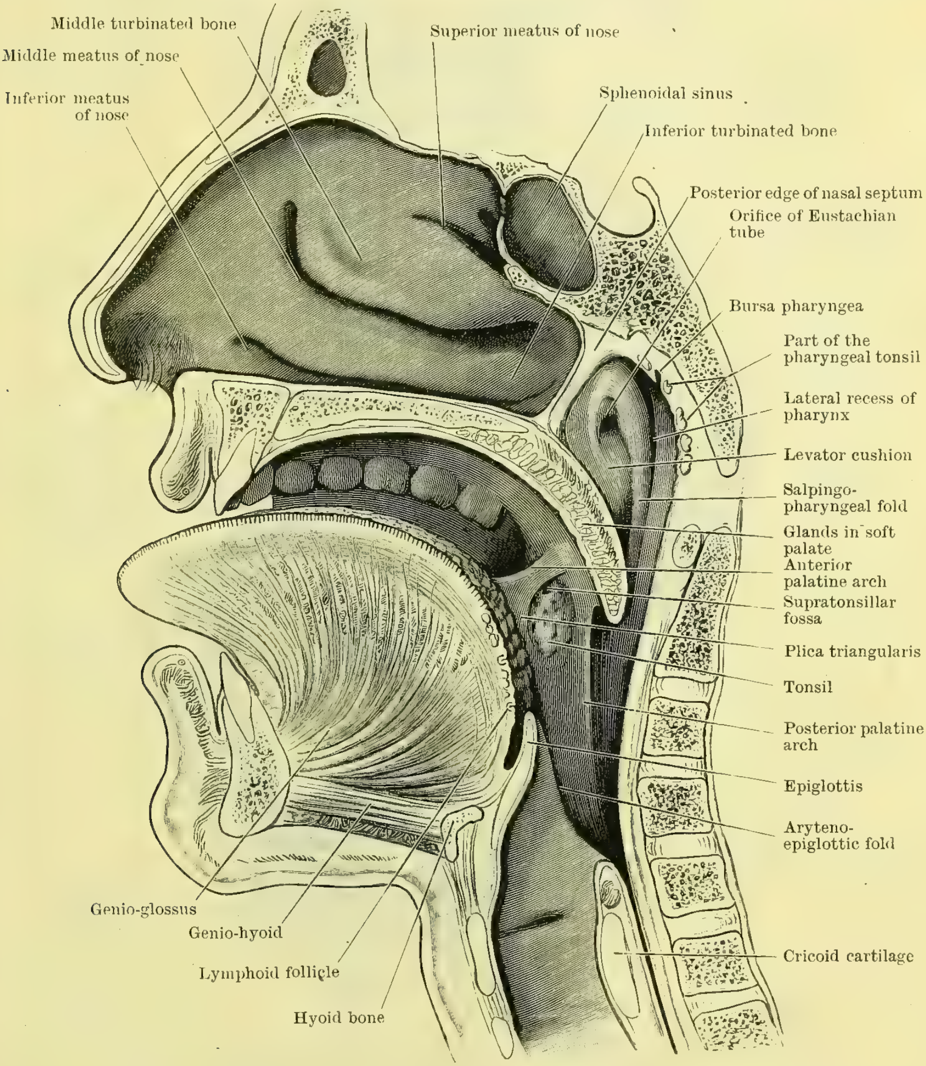


FIG. 639.—SAGITTAL SECTION THROUGH MOUTH, TONGUE, LARYNX, PHARYNX, AND NASAL CAVITY.

The section was slightly oblique, and the posterior edge of the nasal septum has been preserved. The specimen is viewed slightly from below, hence the apparently low position of the inferior turbinated bone.

naked eye, at its centre; the great majority of these are lymphoid follicles (folliculi tonsillares linguales, Fig. 644, C) similar to those found in the tonsils; some few are said to be mucous glands; all are covered by a smooth mucous membrane, and they combine to give to this region a characteristic nodular appearance.

The *mucous membrane* of this portion of the tongue is separated from the muscular substance by a submucous layer in which the lymphoid follicles and the mucous glands lie embedded (Fig. 639). At the sides it is continuous with that covering the tonsils and the side wall of the pharynx; whilst behind it is reflected on to the front of the epiglottis, forming in the middle line a

prominent fold, the **frenulum epiglottidis** or **middle glosso-epiglottic fold** (plica glosso-epiglottica media, Fig. 640), at each side of which is a wide depression, the **vallecula**.

Two lateral glosso-epiglottic folds have been described, but these pass from the side of the epiglottis, not to the tongue, but upwards along the wall of the pharynx, upon which they are soon lost; consequently the term pharyngo-epiglottic is more applicable to them.

The **anterior or oral portion of the dorsum linguæ**, namely, the part in front of the sulcus terminalis (Fig. 640), is convex, both from before backwards and

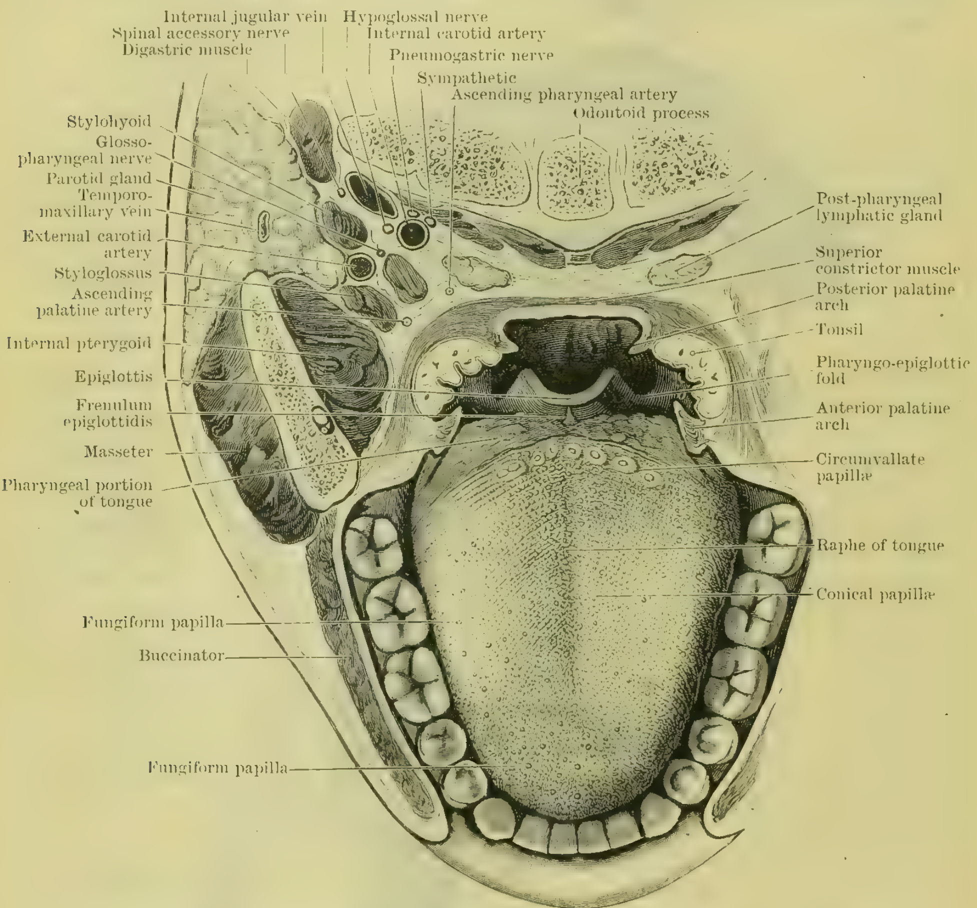


FIG. 640.—HORIZONTAL SECTION THROUGH MOUTH AND PHARYNX AT THE LEVEL OF THE TONSILS.

The stylopharyngeus, which is shown immediately to the inner side of the external carotid artery, and the prevertebral muscles, are not indicated by reference lines.

from side to side in the resting condition of the organ (Fig. 637). It usually presents also a slight median depression, along the centre of which may be seen some indication of a median **raphe** in the form of an irregular crease, which ends posteriorly near the foramen cæcum. The mucous membrane of this portion of the dorsum is thickly covered with the prominent and numerous **papillæ** (papillæ linguales) which give the tongue its most characteristic appearance.

On the pharyngeal part of the tongue there are also small papillary projections of the corium, but the epithelium fills up all the intervals between the papillæ, and, as it were, levels off the surface, so that none are visible to the eye as projections above the general level. Over the anterior part of the tongue, on the contrary, the projections of the corium are large and prominent, and the intervals between them, while they are covered, yet are not filled up, by the epithelium, so that the projections stand out distinctly and independently, and in places attain a height of nearly 2 mm. above the general surface.

Papillæ of the Tongue (Fig. 640).—These are formed by variously-shaped projections of the corium of the mucous membrane, covered by thick caps of epithelium. They are of three different varieties:—1, Conical or filiform (papillæ conicæ, p. filiformes); 2, Fungiform (papillæ fungiformes et p. lenticulares); and 3, Circumvallate (papillæ vallatæ).

The **conical** or **filiform papillæ** (Fig. 642) are the smallest and most numerous, forming as they do a dense crop of minute projections all over the anterior two-thirds of the dorsum, and also upon the upper part of the margin and tip, of the tongue. Posteriorly they are arranged in divergent rows running outwards and forwards from the raphe, parallel to the limbs of the sulcus terminalis. More anteriorly, the rows become nearly transverse, and near the tip irregular. Each papilla is composed of a conical projection of the corium, beset with microscopic papillæ like those of the skin, and covered by a thick long cap of stratified squamous epithelium.

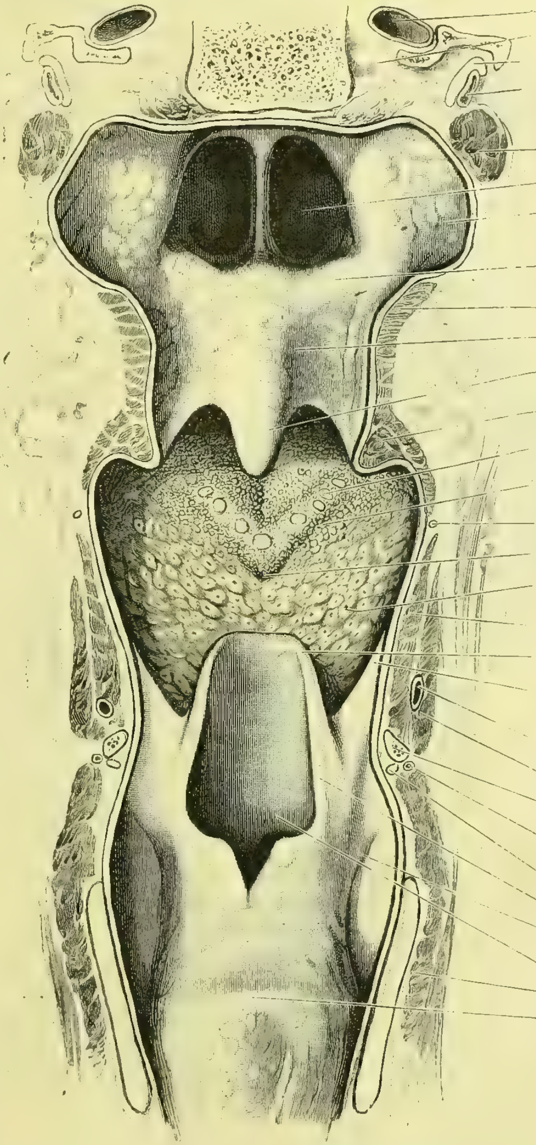


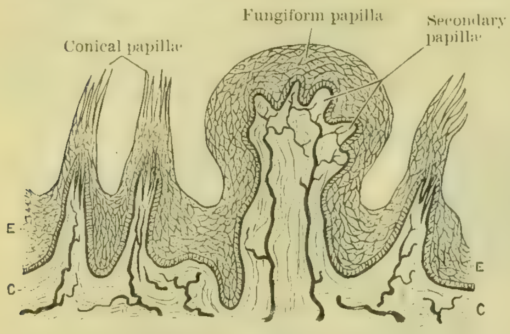
Fig. 641.—The Anterior Wall of the Pharynx with its Orifices, seen from behind.

The specimen from which the drawing was made was obtained from a formalin-hardened body, by removing the posterior wall of the pharynx while leaving the anterior wall undisturbed. The following points should be noted: the greatest width of the pharynx, above, at the lateral recesses; the posterior nares, with the inferior turbinated bones seen through them; the levator cushion; and the pharyngeal portion of the tongue.

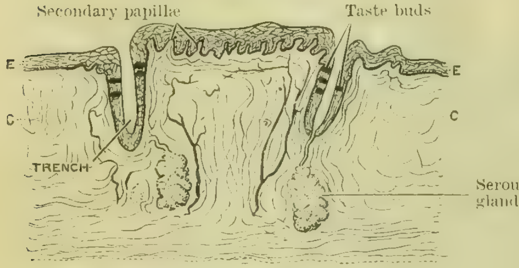
Often, however, the cap of epithelium is broken up into several long slender hair-like processes, giving rise to the variety known as *filiform papillæ*. The cap of epithelium is being constantly shed and renewed, and an excessive or diminished rate of shedding or renewal, coupled with the presence of various fungi, gives rise to the several varieties of "tongue" found in different diseases.

The conical and filiform papillæ are probably of a prehensible or tactile nature, and are highly developed, and horny, in carnivora.

The **fungiform papillæ** (Fig. 642) are larger and redder, but less numerous than the last variety, and they are found chiefly near the tip and margins of the tongue, comparatively few being present over the dorsum generally. Each is in shape like a "puff-ball" fungus (Halliburton), consisting of an enlarged rounded head, attached by a somewhat narrower base. As in the case of the conical papillæ, the corium is studded over with microscopic papillæ, which are buried in the covering of squamous epithelium and do not appear on the surface. Most of the fungiform papillæ, if not all, appear to be furnished with taste-buds, and they are probably intimately connected with the sense of taste.



Conical and fungiform papillæ. ×30.



A circumvallate papilla. ×12.

FIG. 642.—THE PAPILLÆ OF TONGUE.

The upper illustration shows conical and fungiform papillæ, the lower a circumvallate papilla. C. Corium, and E. Epithelium of the mucous membrane. The wavy dark lines represent arteries.

The **circumvallate papillæ** (Fig. 642), by much the largest of all the papillæ of the tongue, are confined to the region immediately in front of the sulcus terminalis and foramen cæcum. Usually about ten in number, they are arranged in the form of the letter V, with the apex backwards, just in front of and parallel to the sulcus terminalis. One or two of the papillæ are usually placed at the apex of the V, immediately anterior to the foramen cæcum. In appearance a circumvallate papilla resembles very closely the impression left by pressing the barrel of a small pen on soft wax (Fig. 641). Each is composed of a cylindrical central part (1 to 2·5 mm. wide), slightly tapering towards its base, and flattened on its crown, which projects a little above the general surface of the tongue. This is surrounded by a deep, narrow, circular trench or **fossa**, the outer wall of which is known as the **vallum**. The vallum appears in the form of an encircling collar very slightly raised above the adjacent surface (Fig. 640).

As in the case of the other forms, the circumvallate papillæ are made up of a central mass of corium, beset with numerous microscopic papillæ on the crowns, but not on the sides, and covered over, as are the surfaces of the fossa and vallum, by stratified squamous epithelium. Into the fossæ open the ducts of some small serous glands (Fig. 642).

On the sides of the circumvallate papillæ, as well as upon the opposed surface of the vallum, are found, in considerable numbers, the structures known as **taste buds**, the special end-organs of the nerves of taste.

The **apex** (apex linguæ), and the **margin** (margo lateralis) of the tongue in front of the attachment of the anterior palatine arch, are free, and lie in contact with the teeth when the tongue is at rest.

On the upper half or more of the margin and apex, papillæ are present as on the dorsum; but on the lower part they are absent, and the surface is covered by smooth mucous membrane.

Just in front of the anterior palatine arch, on the margin, are usually seen about five or six distinct vertical folds, forming the **folia linguæ**, which are beset with taste-buds, and correspond to a well-defined area (the papillæ foliatæ) on the side of the tongue in certain animals (rabbit, hare, etc.), in which it forms an important part of the organ of taste.

The **inferior surface** (facies inferior) of the tongue, which is exposed by turning the apex of the organ upwards, is limited in extent (Fig. 643), and is free from visible papillæ, the surface being covered by a smooth mucous membrane. Running

along its middle, except near the tip, is a depression, from which a fold of mucous membrane, the **frenulum linguæ**, passes down to the floor of the mouth, and on towards the back of the mandible. At each side of the frenulum, and a short distance from it, the large ranine vein is distinctly seen through the mucous membrane. Further out still are situated two indistinct, fringed folds of mucous membrane, the **plicæ fimbriatæ**, which converge somewhat as they are followed forward towards the tip, near which they are lost.

From the inferior surface of the tongue the mucous membrane passes across the floor of the mouth to the inner surface of the gum, with the mucous covering of which it becomes continuous.

The **plicæ fimbriatæ** correspond pretty closely to the course of the ranine arteries as they run towards the tip; the arteries, however, are deeply placed in the substance of the tongue, at a distance of 3 to 6 mm. from the inferior surface. The plicæ, which are more distinct at birth and in the fœtus, are said to correspond to the under tongue found in the lemurs.

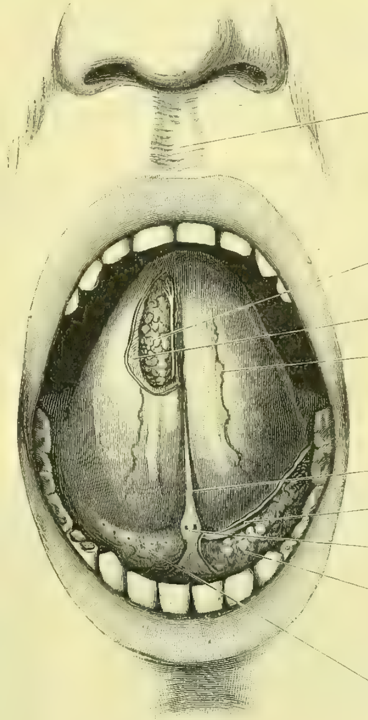


FIG. 643.—OPEN MOUTH WITH TONGUE RAISED, AND THE SUBLINGUAL AND APICAL GLANDS EXPOSED.

The sublingual gland of the left side has been laid bare by removing the mucous membrane; to expose the apical gland of the right side a thin layer of muscle, in addition to the mucous membrane, has been removed. A branch of the lingual nerve is seen running on the inner aspect of the gland. The ranine vein is faintly indicated on this side also.

The **root of the tongue** (radix linguæ) is the portion of the inferior aspect which is connected by muscles and mucous membrane to the mandible and hyoid bone. It is of very considerable extent, and is, with the base, the most fixed part of the organ. It is also the situation at which the vessels and nerves as well as the extrinsic muscles enter.

Structure of the Tongue.—The tongue is chiefly composed of striped muscular tissue, in connexion with which are found a considerable admixture of fine fat and a median septum of connective tissue occupying the central part of the organ. In addition, there are vessels, nerves, glands, and lymphoid tissue, the whole being covered over by mucous membrane, except at the root (Fig. 644).

The muscular tissue is derived partly from the terminations of the extrinsic muscles—namely, the hyoglossus, styloglossus, genioglossus, palatoglossus, and chondroglossus; but also largely from the intrinsic muscles—namely, the superior lingualis, inferior lingualis, the transverse, and the vertical lingual muscles. These are so arranged that they form a **cortical portion**, made up chiefly of longitudinal fibres—derived above from the superior lingualis and the hyoglossus, at the sides from the styloglossus, and below from the inferior lingualis. This cortex surrounds a central or **medullary portion**, divided into two lateral halves by the **septum**, and formed in great part by the transverse and vertical fibres, and also by the fibres of the genioglossi ascending to the dorsum. The muscular fibres derived from these various sources end by being inserted into the deep surface of the mucous membrane.

The detailed description of the extrinsic and intrinsic muscles will be found on page 386.

The **septum** is a median fibrous partition found in the medullary portion only, and easily exposed by separating the two genioglossi on the under surface of the tongue. Anteriorly it usually extends to the apex; whilst posteriorly it grows gradually narrower, and expanding transversely at the same time, it passes into a broad sheet (the

hyoglossal membrane) which is united to the upper border of the hyoid bone, and gives attachment to the posterior fibres of the genioglossus. From the sides of the septum the transverse fibres of the tongue arise.

The **mucous membrane** on the anterior two-thirds of the dorsum, and on the free margins, is firm and closely adherent to the underlying muscular substance, the fibres of which are inserted into it. On the posterior third of the dorsum, and on the inferior surface, it is neither so firm nor so closely united to the muscular substance, from which it is separated in both of these situations by a layer of submucous tissue.

The mucous membrane of the tongue, like that of the rest of the mouth, is covered by stratified squamous epithelium.

Glands of the Tongue.—Numerous small racemose glands are found scattered beneath the mucous membrane of the posterior third of the tongue; and a small collection of similar glands is present at the margin, opposite the circumvallate papillæ. Small serous glands are also found embedded in the dorsum near the circumvallate papillæ, into the fossæ of which their ducts open (Fig. 642).

The chief collections of glandular tissue in the tongue, however, are found embedded in the muscle of the under surface, a little way behind the apex, on each side of the middle line (Fig. 643). They are known as the **apical glands** (glandulæ linguales anteriores of Nuhn or Blandin).

These apical glands are displayed by removing the mucous membrane and also a layer of

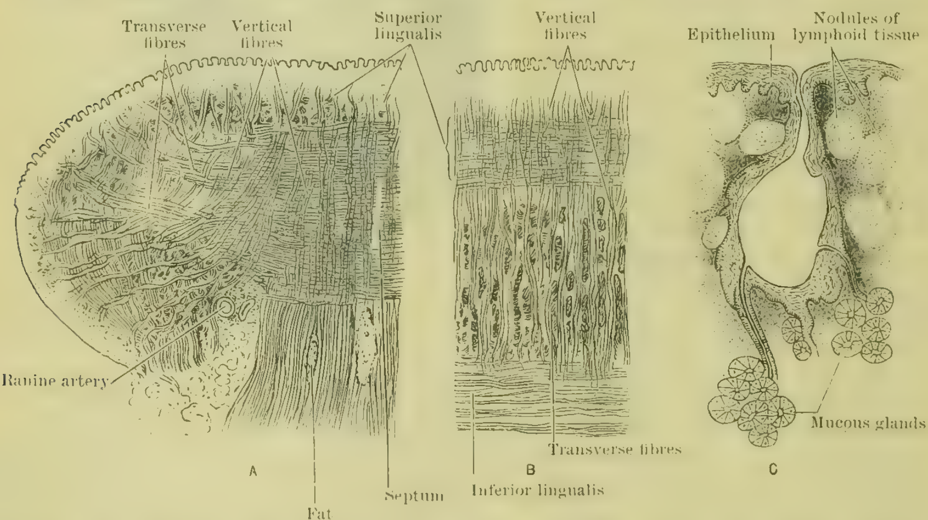


FIG. 644.—A, TRANSVERSE, AND B, LONGITUDINAL VERTICAL SECTION THROUGH THE TONGUE (Krause); C, A LYMPHOID FOLLICLE FROM BACK PART OF TONGUE (Macalister, slightly modified).

muscular fibres (derived from the united inferior lingualis and styloglossus) about 2 mm. in thickness from the under surface of the tongue a little distance behind the apex. They are oval in shape, often partly broken up by muscular fibres, and they measure from $\frac{1}{2}$ to $\frac{3}{4}$ in. (12 to 19 mm.) in length. They are mixed serous and mucous glands, and they open by three or four very small ducts on the inferior surface of the tongue.

Vessels.—The chief *artery* is the **lingual.** This vessel passes forwards on each side beneath the hyoglossus muscle, and then is continued on to the apex—between the genioglossus on the inner side and the inferior lingualis externally—under the name of the ranine artery. Anteriorly it is covered by the fibres of the inferior lingualis, and lies $\frac{1}{8}$ to $\frac{1}{4}$ inch from the surface. Near the apex the arteries of opposite sides are connected by a branch which pierces the septum, but otherwise, with the exception of capillary anastomosis, they do not communicate. The **dorsalis linguæ branch** of the lingual is distributed to the pharyngeal part of the tongue, whilst some twigs of the **tonsillar branch** of the facial are also distributed in the same region.

The *veins* are: the **ranine**, the chief vein, which lies beneath the mucous membrane at the side of the frenum, and runs backwards over the hyoglossus muscle with the hypoglossal nerve; two **venæ comites,** which accompany the lingual artery; and a **dorsalis linguæ vein** from the back of the tongue. These either unite and form a common trunk, or open separately into the internal jugular vein.

Nerves.—The nerves which supply the tongue are: (1) The **hypoglossal,** the motor nerve of the tongue, which enters the genioglossus and passes up in its substance to the intrinsic muscles, in which it ends. (2) The **lingual,** a branch of the inferior maxillary nerve, which is accompanied by the **chorda tympani branch** of the facial. The lingual, after crossing the hyoglossus muscle, breaks up and enters the inferior lingualis and genioglossus, and thus makes its way upwards to the mucous membrane of the anterior two-thirds of the tongue—the lingual itself conferring common sensation on this part, the chorda tympani probably carrying to it taste

fibres. (3) The **glossopharyngeal nerve** passes forwards beneath the upper part of the hyoglossus, and sends its terminal branches to the mucous membrane of the posterior third of the tongue, supplying the circumvallate papillæ, and the part of the tongue behind these, with both gustatory and common sensory fibres. (4) The **internal laryngeal nerve** also distributes a few fibres to the posterior part of the base of the tongue, near the epiglottis.

The **lymphatics** of the anterior half of the tongue pass down through the floor of the mouth and join the **submaxillary lymphatic glands.** Those from the posterior half run with the ranine vein across the hyoglossus muscle (where they are connected with some small lingual glands) and join the **deep cervical glands.**

GLANDS.

Various organs, differing widely both in structure and function, are commonly included under the general term glands. It is made to embrace: (*a*) the *glands with ducts,* such as the digestive glands (liver, pancreas, salivary glands, etc.), the sweat and sebaceous glands of the skin, the testes, etc., and the small glands embedded in the walls of the digestive and respiratory tracts; (*b*) the so-called *ductless glands* (spleen, thyroid, suprarenals, etc.), which possess no ducts, but throw their secretions into the blood or lymph passing through them; and (*c*) the *lymphatic glands,* which cannot properly be classified under either of the other groups. We shall here consider only the true glands—namely, those included in the first group mentioned above, which are all characterised by the possession of ducts; and what follows refers to them alone.

A **gland** may be defined as an epithelial organ which separates or elaborates from the blood some substance which is either to be discharged from the body or used further in the economy. The product of the activity of the gland is known as its secretion, and the secretion is conveyed to its destination in all true glands, as explained above, by the gland duct.

Every gland is primarily an outgrowth of the epithelium from the surface to which the secretion of the gland is to be subsequently conveyed. This outgrowth may remain undivided, constituting a **simple gland.** On the other hand, it may break up into two or more branches, giving rise to a **compound gland.** We thus arrive at the two great classes of glands—simple and compound.

A **simple gland** may remain tubular, when it is known as a *simple tubular gland,* of which Lieberkuhn's follicles in the wall of the small intestine and the sweat glands are examples. Or it may be dilated at its extremity, the enlargement being known as an acinus (ακινος, a grape or grape-stone) or alveolus, thus constituting a simple *acinous* or *alveolar gland,* of which there are few examples in man (viz. some sebaceous glands), though they are numerous in the skin of the frog, etc. This gives us two varieties of simple glands—tubular and acinous or alveolar.

Similarly a **compound gland** may remain tubular, constituting a *compound tubular gland,* such as the kidney, testicle, and the majority of the gastric glands. Or, on the other hand, the terminal branches of its ducts may be beset with dilatations (*i.e.* acini or alveoli), giving rise to a *compound acinous* or *alveolar gland,* which latter, owing to a remote resemblance presented by its clustering lobules to a miniature bunch of grapes, is often known as a *racemose gland* (*racemus,* a cluster). Most of the glands of the body are examples of this variety—*e.g.* the salivary glands, the small glands of the mouth, tongue, pharynx, œsophagus, respiratory passages, eyelids, etc. Thus we arrive at two varieties of compound glands also—tubular and acinous or alveolar.

A compound acinous (racemose) gland is composed of a main duct which branches and re-branches more or less freely according to the size of the gland, and the terminal divisions of which end finally in specialised secreting parts, the acini or alveoli, quite distinguishable from the ducts or conducting parts. In true acinous glands the acini or alveoli are distinctly saccular; in other glands, such as the pancreas, this is not the case, the acini being long and narrow. Accordingly, the term *acino-tubular* has been introduced and applied to glands of this latter type, which is usually made to include the pancreas, the prostate, and Brunner's glands.[1]

It should be added that the term acino-tubular is by some authors used exclusively instead of acinous for all racemose glands.

There is one gland, however, which cannot be included in any of the above varieties, and which must be placed in a class by itself. This is the liver. It is composed of an enormous number of small secreting lobules, between which run the branches of the bile-duct. These lobules in the mammalian liver cannot in any way be compared to acini, or to collections of acini, as their cells are not arranged around a central lumen, but form a practically solid mass, with minute bile capillaries running everywhere between them. It might in mammals, for want of a better term, be classed as a *solid gland.*

The foregoing may be summarised in tabular form thus:—

I. **Simple glands.**—Duct undivided.
  (*a*) **Simple tubular.**—Undilated at end—*e.g.* Lieberkühn's follicles, sweat, and many gastric glands.
  (*b*) **Simple acinous** (alveolar or saccular).—Dilated at end—*e.g.* some sebaceous glands (rare).

[1] Some authorities consider the glands of Brunner to belong to the class of compound tubular glands (Heidenhain, Watney, Jonnesco, etc.).

II. **Compound glands.**—Duct divided.

(*a*) **Compound tubular.**—Branched elongated tubes, no acini—*e.g.* testes, kidney, most gastric glands.

(*b*) **Compound acinous or alveolar** (racemose glands), branched duct with saccular acini on terminal branches—*e.g.* salivary, sebaceous, and Meibomian glands; the mucous glands of the mouth, tongue, palate, pharynx, nose, œsophagus, and respiratory tube.

(*c*) **Acino-tubular.**—Branched duct, with elongated narrow acini on terminal branches—*e.g.* pancreas, Brunner's glands, prostate.

III. **Solid gland.**—The liver.

To save confusion it may be pointed out that instead of acinus the term alveolus (and also saccule and follicle) is often used, and also that the term "racemose gland" is often conveniently used instead of compound acinous gland.

General Structure of Glands.—Whilst the small glands, such as those of the mouth and pharynx, are placed in the mucosa or submucosa immediately beneath the point at which their ducts open on the surface, the large glands form distinct masses, generally surrounded by special capsules, and often lie at a considerable distance from the points at which their ducts open.

One of these large glands of the acinous type, such as the parotid or submaxillary, presents the following general arrangement. The gland is made up, as can be seen with the unaided eye, of a number of masses, often as large as peas, which are surrounded and held together by connective tissue. These are known as lobes, and to each a branch of the duct passes. The lobes are in turn made up of a number of smaller masses—lobules—each having a special branch of the lobar duct. These again are composed of smaller lobules, and so on to a varying degree. Finally, the smallest are made up of a terminal branch of the duct, with a cluster of acini or alveoli developed upon it.

The **acini** or **alveoli**, the special secreting portions of the gland, are composed of a basement membrane, often fenestrated or basket-like, formed of flattened cells, on the outer side of which the blood and lymph vessels lie. The inner surface of this membrane is lined by the secreting epithelial cells, usually polygonal in shape, which almost completely fill the alveolus. A small lumen, however, is left, into which the secretion of the cells is shed, whence it passes into the duct of the lobule, and thus to the main duct.

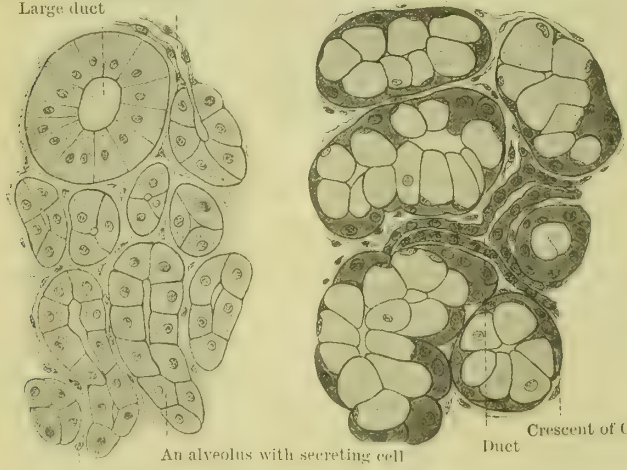


FIG. 645.—SECTION OF A SEROUS GLAND ON THE LEFT, A MUCOUS GLAND ON THE RIGHT SIDE (Böhm and v. Davidoff).

In the serous gland the granular secreting cells and the centrally-placed nucleus should be noted. The relatively clear cells, with the dark crescents of Gianuzzi, are distinctive in the mucous gland.

The blood-vessels and lymphatics, on entering the gland, break up and run, branching as they go, in the connective tissue which conveys them to all parts of the gland.

Mucous and Serous Glands.—Two distinct varieties of salivary glands are found, the serous and the mucous, differing not only in the nature of their secretion, but also in the character of the epithelium lining their alveoli. In those of the mucous type (Fig. 645) the epithelial cells are large, clear, or faintly granular, and the nucleus lies as a rule near the base of the cell. In addition, many mucous glands, but not all, have small flattened or crescentic cells, distinctly granular, which stain strongly with ordinary stains, lying between the basement membrane and the bases of the chief cells. These are the *crescents* or *demilunes of Gianuzzi*.

In the acini or alveoli of serous glands, on the other hand (Fig. 645), the epithelial cells are distinctly granular, the granules staining well with ordinary stains; the nuclei are rounded and lie near the centre of the cells, and no demilunes are present.

In man the parotid and the small glands which open into the fossæ of the circum-

vallate papillæ alone are *serous*. The submaxillary and the apical gland of the tongue are *mixed*, the serous alveoli being the more numerous; whilst the sublingual, labial, buccal, and all other glands of the mouth, tongue, and palate are said to be *mucous*.

Salivary Glands.

This term is generally understood to include only the three large masses of glandular tissue found on each side of the face—namely, the parotid, submaxillary, and sublingual glands. But, as previously pointed out, numerous other small glands

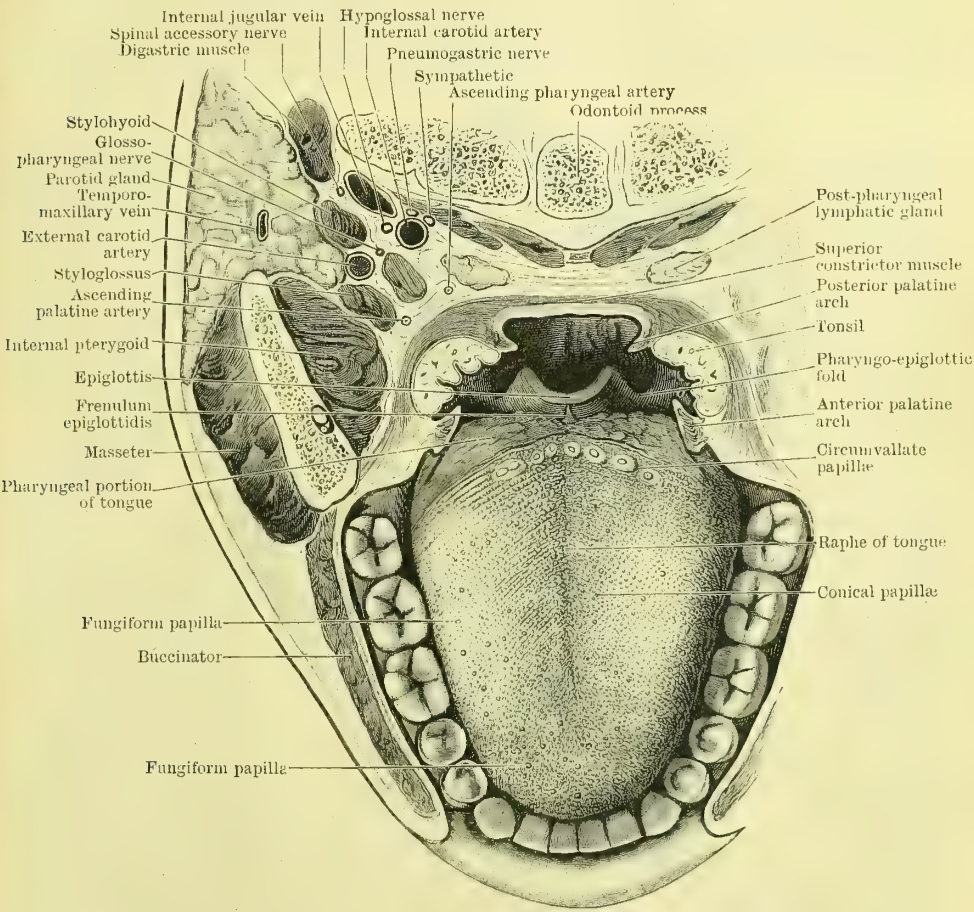


Fig. 646.—Horizontal Section through Mouth and Pharynx at the Level of the Tonsils.

The stylopharyngeus, which is shown immediately to the inner side of the external carotid artery, and the prevertebral muscles, are not indicated by reference lines.

of a similar nature are found in the lips, cheeks, palate, tongue, etc. These have already been sufficiently described, and require no further mention.

Parotid Gland (glandula parotis).—This, the largest of the salivary glands, is a distinctly lobulated mass of a yellowish or light reddish-brown colour, which is placed in a deep recess (the parotid recess) at the side of the head, below and in front of the ear (Fig. 647). It extends up to the zygoma, down to the angle of the jaw or even to a lower level, and backwards to the sterno-mastoid muscle. Internally it lies on the styloid process, and anteriorly its facial process is continued for a variable distance over the surface of the masseter.

When the gland is carefully removed without disturbing the surrounding parts, the recess which it occupies is seen to be a considerable space, between the ramus of the jaw in front and the sterno-mastoid muscle behind, with a floor formed of two sloping walls, an anterior and a posterior, which meet at an angle corresponding pretty

closely to the styloid process. Thus the recess is three-sided (Fig. 646), the third side corresponding to the parotid fascia covering the gland. Into this **parotid recess** the greater part of the parotid gland fits closely. From its anterior part, however, the variably-developed **facial process** is continued forward over the masseter muscle.

Parotid Fascia.—The parotid recess is covered over on the one hand, and lined on the other, by fascia. The covering layer is specially known as the parotid fascia, and both it and the lining layer are derived from the deep cervical fascia, which divides below to enclose the gland. The parotid fascia proper is connected above to the zygoma; behind, to the auditory meatus and anterior border of the sterno-mastoid; below, it is continuous with the deep cervical fascia, and in front it passes forwards over the masseter, and joins the fascia of that muscle. The layer of fascia beneath the gland forms a lining for the recess, and is united above to the periosteum over the auditory meatus and back part of the glenoid fossa; internally it is connected to the styloid process; whilst below it joins the deep cervical fascia. Taken together, the two layers form a definite capsule which completely encloses the gland. In connexion with the lower and anterior part of this capsule is developed a special flat band, the **stylo-mandibular ligament**, which passes downwards and outwards from the styloid process to the angle of the jaw. It separates the anterior part of the parotid gland from the back of the internal pterygoid muscle; perhaps occasionally, also, from the upper and posterior part of the submaxillary gland.

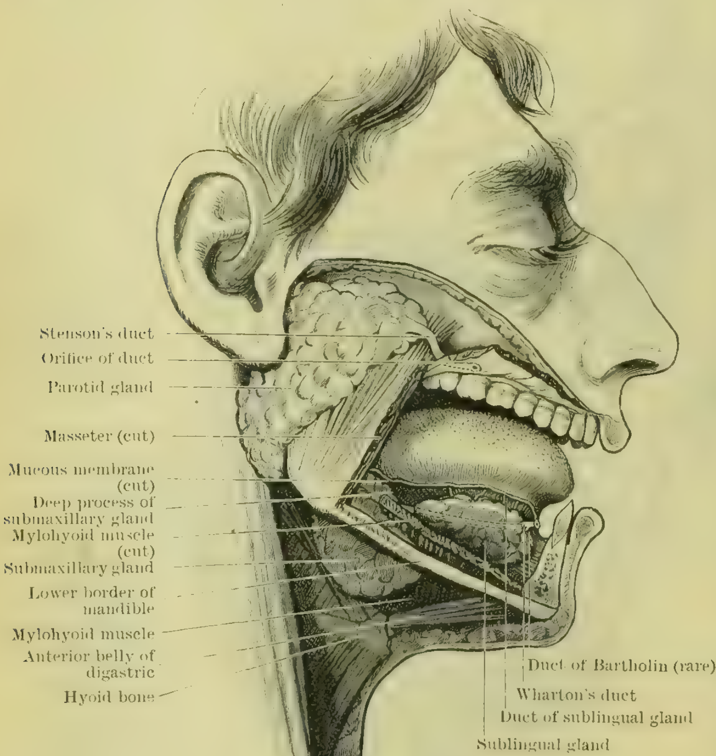


FIG. 647.—THE SALIVARY GLANDS AND THEIR DUCTS.

The greater portion of the body of the mandible has been removed to expose the sublingual and the deeper parts of the submaxillary glands. Four ducts of the sublingual gland are shown opening on the floor of the mouth over the gland, a fifth is shown opening into the anterior end of Wharton's duct. The course of Wharton's duct is shown by a dotted line.

Shape and Relations of the Parotid Gland.—Like the recess in which it lies, the main mass of the parotid gland is three-sided (Fig. 646), the three surfaces being superficial, anterior, and posterior.

The *superficial surface* is closely covered by the parotid fascia, and its lower part is also crossed by the highest fibres of the platysma. The *anterior surface*, approximately flat, lies in contact with the wide posterior surface of the internal pterygoid muscle; it is also related to the posterior border of the mandible and the masseter muscle, whilst from its superficial part the **facial process** is continued forwards over that muscle. The *posterior surface* lies from without inwards against (1) the anterior border of the sterno-mastoid and the auditory meatus, (2) the posterior belly of the digastric and the occipital artery, and (3) the spinal accessory nerve and carotid sheath—the internal jugular vein within the sheath being in very close relation. The *inner angle* formed by the meeting of the anterior and posterior surfaces corresponds to the styloid process and the styloid muscles (Fig. 646). *Above,* the gland is limited superficially by the zygoma; more deeply a thin process runs up into the posterior part of the glenoid

fossa. *Inferiorly* it usually reaches a little distance below a line prolonged horizontally backwards from the angle of the jaw, but its limit in this direction is variable.

Occasionally the parotid gland passes down a considerable distance below the angle of the mandible, lying here superficial to the posterior part of the submaxillary gland, from which it is separated by a thickened band of the deep cervical fascia, passing from the angle of the jaw to the fascia of the sterno-mastoid. At other times it does not quite reach the angle.

The **facial process** of the gland—often of considerable size—is a flat and somewhat triangular portion which runs forwards from the upper part of the gland, covering the masseter muscle to a varying extent; from its most anterior part the parotid duct emerges, and a separated portion of this process, often found lying immediately above the duct, is known as the **socia parotidis** (glandula parotis accessoria).

Traversing the substance of the gland (Fig. 646) are found:—(1) the temporo-maxillary vein; (2) on a deeper plane, the branches of the facial nerve passing forwards; and (3) more deeply still, the external carotid artery which lies beneath the lower part of the gland, but is embedded in its deep surface above: just before it emerges, the artery divides into its two terminal branches in the gland substance.

The **parotid** or **Stenson's duct** (ductus parotideus) leaves the anterior border of the gland at its most prominent part (Fig. 647). It first runs forwards across the masseter, usually accompanied by the socia parotidis which lies above it, and also by branches of the facial nerve; whilst the transverse facial artery is commonly some distance above, though its relation is variable. Having crossed the masseter, it arches round the anterior border of this muscle and runs inwards through the fat of the cheek, practically at right angles to the first part of its course, to reach the buccinator, which it pierces. Then passing for some distance (5 to 10 mm.) between the buccinator and mucous membrane, it opens into the vestibule of the mouth by a very small orifice, on a variably-developed papilla, opposite the crown of the second upper molar.

The course of the duct, which is fairly constant, can be marked on the side of the face by drawing a line from the lower edge of the auditory meatus to a point midway between the ala of the nose and the red of the lip; the middle third of this line corresponds fairly accurately on the surface, to the course pursued by the duct.

The gland varies in weight from half an ounce to an ounce or more. Several small lobes or processes are found in connexion with it—viz. one running backwards between the sterno-mastoid and the digastric; a glenoid lobe of very small size, which lies in the posterior part of the glenoid cavity; a pharyngeal process (Fig. 646), which runs forwards and inwards between the styloid process and the external carotid artery towards the pharynx. A pterygoid extension running forwards between the two pterygoid muscles, although described, cannot properly be said to exist.

Stenson's duct measures from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches (38 to 62 mm.) in length, and $\frac{1}{8}$ inch (3 to 4 mm.) in diameter. The calibre of the duct is very much greater than that of its orifice, which only admits a fine bristle, and for this reason the duct may, to some extent, be looked upon as a reservoir for the saliva, as well as a duct for its conveyance. In the child it pierces the "sucking pad" on its way to the mouth.

Vessels and Nerves.—The **arteries** which supply the gland arise from the external carotid, and from the branches of this artery in relation to the gland.

The **veins** join the temporo-maxillary and its tributaries. The **lymphatics** pass to both the superficial and the deep cervical glands; there are also a few small parotid lymphatic glands, which lie on the surface of the upper and lower part of the parotid beneath the capsule. Some are said to be embedded in the substance of the parotid itself.

The **nerves** are derived (*a*) from the auriculo-temporal, and (*b*) from the sympathetic on the external carotid. The fibres of the sympathetic are mainly vaso-constrictor. Those of the auriculo-temporal convey to the gland secretory fibres from the glosso-pharyngeal.

Submaxillary Gland.—The submaxillary gland is next in size to the parotid, and resembles it in its lobulation and colour. It is placed partly in the submaxillary triangle and partly under cover of the posterior part of the mandible near its angle (Fig. 647).

In size and shape it may be compared to a small walnut with three flattened

sides. It is enclosed in a complete capsule derived from the deep cervical fascia: embedded in this capsule, and superficial to the gland, are found a few submaxillary lymphatic glands, which are of importance owing to their connexion with the lymphatics of the lips and of the anterior half of the tongue.

In considering the relations of the gland, it is well to remark that there is in this region a three-sided space bounded externally by the inner surface of the mandible below the mylohyoid ridge, internally and above by the mylohyoid muscle running inwards and downwards, and below by the skin and fascia passing from the margin of the jaw obliquely inwards and downwards to join the side of the neck. In this space the gland lies with external, internal, and inferior surfaces corresponding to the walls of the space.

The *superficial* or *inferior surface* looks downwards and outwards; it is covered by the deep cervical fascia and the platysma, and is crossed by the facial vein, which lies superficial to the gland, whilst the artery passes in part beneath it. The *external surface* rests against the inner aspect of the lower jaw (submaxillary fossa) for an inch and a half forward from the angle, to which latter it usually reaches behind. The *deep* or *internal surface* lies on the posterior part of the mylohyoid muscle, and behind this, on the hyoglossus and the posterior belly of the digastric with the stylohyoid: for the gland is not contained within the limits of the submaxillary triangle inferiorly, but passes down some little distance over the digastric muscle. From the deep surface, anterior to its middle, a narrow tongue-like **deep process** (Fig. 647) is continued forwards beneath the mylohyoid muscle along with the duct.

The *posterior end* of the gland, which is its most bulky portion, either abuts against, or lies very close to, the sterno-mastoid, and is often overlapped by the lower end of the parotid gland. The facial artery, on its way to the border of the mandible, lies in a groove in the upper and back part of the gland.

The **submaxillary** or **Wharton's duct** leaves the deep surface of the gland about its middle, and runs forwards beneath the mylohyoid muscle with the deep process, along the upper and inner aspect of which it is placed (Figs. 646 and 643). Pursuing its course forwards beneath the floor of the mouth, on the inner side of the sublingual gland, the duct crosses the hyoglossus and the genioglossus muscles, and finally opens on the floor of the mouth at the side of the frenulum linguæ, where its small orifice is placed on the summit of a soft papilla (caruncula sublingualis) close to its fellow of the opposite side.

While running forward beneath the floor of the mouth the duct, which is about two inches long (50 mm.), is crossed on its inferior aspect by the lingual nerve near the anterior border of the hyo-glossus, that is opposite the 2nd molar tooth. The nerve at the time is arching from the posterior end of the mylo-hyoid ridge (against which it lies) inwards and forwards in order to reach the under surface of the tongue, and in this course it passes beneath the duct at the point indicated. As in the case of Stenson's duct, the calibre of Wharton's duct is much greater than that of the orifice by which it opens; for this reason it may likewise be looked upon as forming, to some extent, a reservoir for the saliva secreted by the gland.

Vessels and Nerves.—The **arteries** come chiefly from the facial and its submental branch: the **veins** are similarly disposed. The **nerves** are derived from the submaxillary ganglion (which lies above the deep process of the gland), and are composed of fibres from the chorda tympani, from the lingual, and from the sympathetic on the facial artery. The lymphatics pass to the submaxillary lymphatic glands.

Sublingual Gland.—This is an elongated almond-shaped mass, flattened from side to side, and much wider (from above downwards) in front than behind, which lies on the floor of the mouth beneath the plica sublingualis—a ridge of the mucous membrane produced by the prominent upper border of the gland. It is usually from $1\frac{1}{2}$ to $1\frac{3}{4}$ inches (37 to 45 mm.) in length, whilst its bulk is about equal to that of two or three almonds.

It is placed between the mandible externally, the genioglossus internally, the mylohyoid muscle below, and the mucous membrane of the mouth above (Fig. 637).

Its detailed relations are as follows:—Its *outer surface* rests against the inner aspect of the body of the mandible above the mylohyoid ridge. Its *inner surface* is in contact with the genioglossus and the hyoglossus muscles, as well as with Wharton's duct, which runs forwards between the gland and the muscles. *Below*, it rests on the mylohyoid, and at its posterior part on the deep process of the submaxillary gland; whilst its *upper*

prominent border is covered only by the mucous membrane of the mouth, here raised up by the gland to form the plica sublingualis (Fig. 643). The anterior portion of the gland is much deeper and more bulky than the posterior half, and it meets its fellow in the middle line beneath the frenulum linguæ. The posterior extremity grows gradually more slender, and ends near the posterior part of the mylohyoid ridge, where it lies above the deep process of the submaxillary gland.

Its **ducts**, generally known as the **ducts of Rivinus** (ductus sublinguales minores), are numerous and of small size; they leave the upper part of the gland, and, after a short course, open on a series of papillæ, visible to the naked eye, which are placed along the summit of the plica sublingualis.

The gland is not enclosed in a distinct capsule, thus differing from the parotid and submaxillary glands; but its numerous lobules, which are smaller than those of the glands just mentioned, are held together by fine connective tissue, loosely, but still in such a manner as to make one more or less consolidated mass out of what was, in the embryo, a number of separate glands.

As a rule all the ducts open separately on the summit of the plica sublingualis, and apparently none of them join Wharton's duct. Frequently some of those from the anterior and more bulky part of the gland are larger than the others, but the presence of a large duct running alongside of Wharton's duct, and opening with or beside it (ductus major Rivini, duct of Bartholin), is very rare, and must be considered as an exceptional condition in man, although normal in the ox, sheep, and goat. The same may also be said of ducts from the sublingual, which are described as opening into the duct of Wharton.

Vessels and Nerves.—The **arteries** are derived from the sublingual branch of the lingual and from the submental branch of the facial. The **nerves** come from the lingual, the chorda tympani, and the sympathetic, through a branch of the submaxillary ganglion which joins the lingual, and is conveyed by it to the gland.

The **apical gland** of the tongue (Nuhn's) is described with the tongue, p. 956.

Development of the Salivary Glands, Palate, and Tongue.

The general development of the lips, mouth, palate, and tongue is described on pages 35 to 40, and reference will be made here only to a few special points connected with these parts.

Several explanations of the formation of the **philtrum** or groove on the front of the upper lip have been put forward; most probably it is produced by the union of the median fronto-nasal process with the two maxillary processes (see p. 38), the floor of the groove being formed by the fronto-nasal process, and the ridges bounding the groove at the sides corresponding to the line of meeting of the fronto-nasal with the maxillary processes.

The **salivary glands** are developed as *solid* outgrowths of the buccal epithelium, one each for the submaxillary (the first developed) and the parotid, several for the sublingual gland. The outgrowths are at first simple; they subsequently divide, and finally develop alveolar enlargements on their extremities. By a separation of the lining cells, the ducts, and later on (about the 22nd week) the alveoli become hollowed out, and present a lumen as in the adult.

The development of the **palate** is given at page 39; but it should be mentioned that, in order to account for the position which the fissure in cleft palate usually occupies, viz. between the central and lateral incisors, the theory has been advanced by Albrecht, that each premaxilla is made up of two separate segments, an inner (or endo-gnathion), containing the central incisor, and an outer (or meso-gnathion), containing the lateral incisor (the rest of the maxilla constituting the exo-gnathion). Between these two segments of the premaxilla (endo- and meso-gnathion) the cleft is said to run, and not between the premaxilla and maxilla as usually held.

Tongue.—The tongue is developed in the embryo, not on the floor of the mouth, but in connexion with the anterior wall of the pharynx, and in two parts, which are at first distinct but soon unite. The anterior two-thirds of the organ is formed from the **tuberculum impar**, a single median elevation, developed on the ventral wall of the pharynx, immediately behind the first, or mandibular, visceral arch. Behind the tuberculum impar, at first, lies a prominent elevation—the **furcula**, from which the epiglottis is formed—the two being separated by a distinct sulcus, the **sinus arcuatus** (see p. 35). Soon, however, the ventral extremities of the second and third visceral arches, growing downwards, unite across the middle line, and separate the tuberculum from the furcula, thus dividing the middle portion of the sinus arcuatus into an anterior and a posterior part. The ventral ends of the two arches having fused, develop, after a little time, into a prominent semilunar ridge, the rudiment of the posterior third of the tongue. This ridge

embraces the back of the tuberculum impar, but it is separated from it in part by the anterior division of the sinus arcuatus, which persists even in the adult as the foramen cæcum, with the sulcus terminalis running forwards and outwards on each side from it. Finally, the two rudiments of the tongue—the tuberculum impar and the semilunar ridge—become blended, the only indication of the original separation being the foramen cæcum, the sulcus terminalis, and the different characters which the mucous membrane presents on the two divisions of the organ. At the foramen cæcum the downgrowth which gives rise to the isthmus of the thyroid gland takes place, and a part of the thyro-glossal duct which in the early condition connects the two may sometimes be found in the adult in connexion with the foramen.

THE TEETH.

The teeth are highly modified portions of the mucous membrane of the mouth, specially developed to perform the important function of mastication, that is, the division and trituration of the food which takes place in the mouth before the *bolus*, as the resulting mass is called, can be swallowed. Each tooth is a calcified papilla of the mucous membrane of the mouth, and consists like that membrane of two chief portions—namely, the dentine derived from the connective tissue, and the enamel from the epithelial layer of the mucous membrane. The **dentine** constitutes the chief mass of the tooth, whilst the **enamel** forms a cap for the portion which projects above the gum. There is also found in the teeth another special tissue—the **cementum** or **crusta petrosa,** a form of modified bone—which encases the roots, these latter being formed chiefly of dentine.

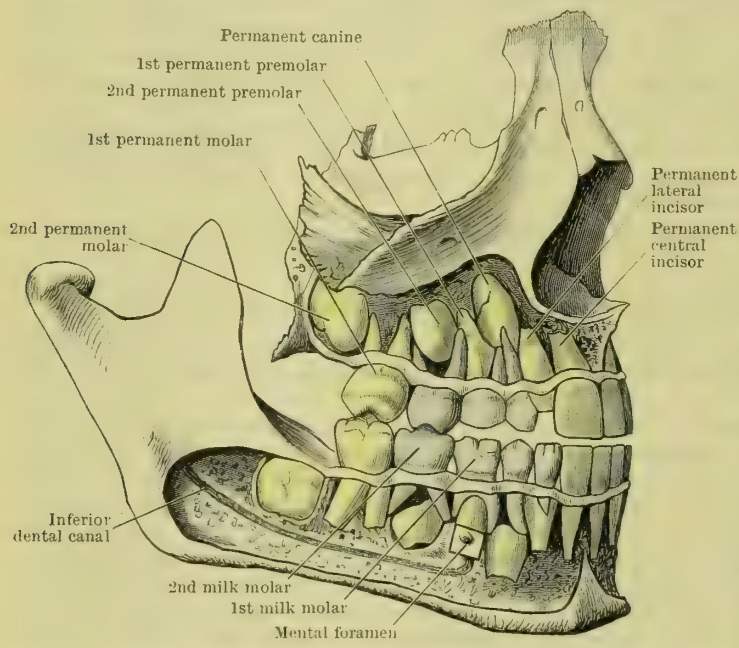


Fig. 648.—Teeth of a Child over Seven Years old (modified from Testut). By removing the bony outer wall of the alveoli, the roots of the teeth which have been erupted, and the permanent teeth which are still embedded in the mandible and maxilla, have been exposed. The milk teeth are coloured blue, the permanent teeth yellow. It will be seen that the first permanent molars have appeared, the central and lateral milk incisors have been replaced by the corresponding permanent teeth in the upper jaw, but the milk canine and molars have not yet been shed. In the lower jaw the central milk incisor has been replaced by the permanent central; the lateral has not yet been shed, but its permanent successor is making its way up to the surface on its lingual side. In addition, the canine and two molars of the milk set persist. The position of the crowns of the permanent teeth between the roots of the milk molars, and the deep situation occupied by the permanent canines, should be noted. Observe also the absorption of the root of the lower lateral incisor

Dentine and enamel, but particularly the latter, are the hardest and most resistant structures in the body, and are thus specially fitted for the functions which they have to perform.

Temporary and Permanent Teeth.—The mouth of the infant at birth contains no teeth, although a number, partly developed, lie embedded in the jaws beneath the gum. Some six months later teeth begin to appear, and by the end of the second year a set, known as the **milk teeth,** twenty in number, has been "cut." Then follows a pause of about four years, during which no visible change takes place in the mouth, although in reality an active preparation for further development is going on beneath the gum.

At the end of this period, namely, about the sixth year, the next stage in the production of the adult condition begins. It consists in the eruption of four new teeth—the first permanent molars—one on each side, above and below, behind those of the milk set. This is followed by the gradual falling out of the twenty teeth which have occupied the mouth since the second year (Fig. 648), and the substitution for them of twenty new teeth, which take up, one by one, the vacancies created by the dropping out of each of the milk set. Finally, the adult condition is attained by the eruption of eight additional teeth—the 2nd and 3rd molars—two on each side, above and below, behind those which have already appeared. All of these—the **permanent set**—have appeared by the end of the twelfth or thirteenth year, except the four wisdom teeth, which are usually cut between the seventeenth and twenty-fifth year, but are often delayed until a very much later period, and occasionally never appear.

The set of teeth which, as indicated above, begin to appear in the infant about the sixth month, are known as the **deciduous, temporary,** or **milk teeth** (dentes decidui), whilst those which succeed them and form the adult equipment are the **permanent teeth** (dentes permanentes).

The **milk teeth** are twenty in number, and are named as follows in each jaw, beginning at the middle line:—central incisor, lateral incisor, canine, first molar and second molar; or more briefly, two incisors, one canine, two molars. This is conveniently expressed by the "dental formula" for the deciduous teeth in man, which shows the number of each class of teeth above and below on one side of the mouth, viz.:—

$$i. \tfrac{2}{2},\ c. \tfrac{1}{1},\ m. \tfrac{2}{2}.$$

The **permanent teeth,** thirty-two in number, are named in each jaw, beginning at the middle line:—central incisor, lateral incisor, canine, 1st premolar (or bicuspid), 2nd premolar (or bicuspid), 1st molar, 2nd molar, and 3rd molar or wisdom tooth (dens serotinus). The dental formula for the permanent set in man is thus:—

$$i. \tfrac{2}{2},\ c. \tfrac{1}{1},\ pm. \tfrac{2}{2},\ m. \tfrac{3}{3}.$$

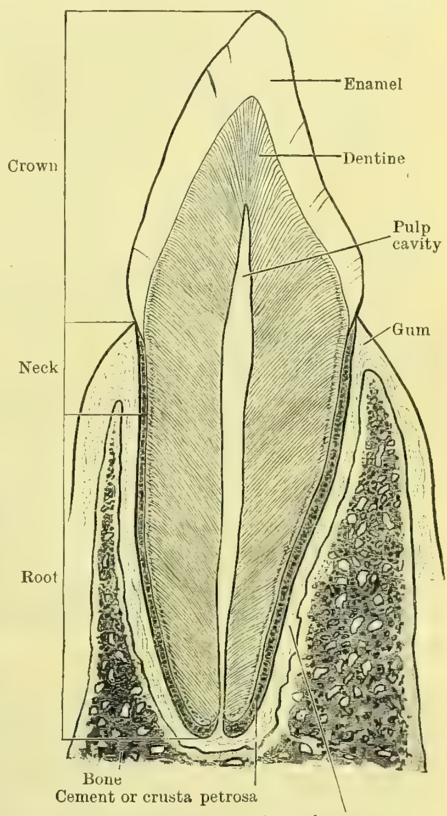


FIG. 649.—VERTICAL SECTION OF CANINE TOOTH, to illustrate its various parts, and its structure.

General Form and Structure.—A tooth consists (Fig. 649) of (1) the **crown** (corona dentis), the portion projecting above the gum, which varies in shape in the different teeth, and in all, except the incisors and canines, bears on its head or grinding surface a number of tubercles or **cusps** (tubercula coronæ), varying in number from two to five in the different teeth; (2) the **neck** (collum dentis), the faintly constricted part which is surrounded collar-wise by the gum, and which connects the crown with (3) the **root** (radix dentis), the portion of the tooth which is embedded in the alveolus of the maxilla or the mandible. In the majority of teeth, namely, in all except the molars, the root, as a rule, is single, or nearly so, and consists of a long, tapering, conical, or flattened piece, perfectly adapted to the alveolus in which it lies. In the molar teeth (and in some of the others occasionally) the root is divided into two or three tapering or flattened **roots** or fangs. At the apex of each root there can be made out, even with the naked eye, a minute opening (foramen apicis) through which the vessels and nerves enter the tooth.

On making a section of a tooth (Fig. 649), it will be seen that the interior of the body is occupied by a cavity of some size, generally called the **pulp cavity** (cavum dentis), owing to the fact that it is filled in the natural state by the soft and sensitive tissue known as the **pulp**. This pulp cavity gradually narrows below, and is prolonged into each root of the tooth as a slender tapering passage, the **root canal** (canalis radicis), which opens at the apical foramen already referred to. Through these root-canals, which also contain some pulp, the vessels and nerves, which enter at the apex, pass to the interior of the tooth.

Short diverticula of the pulp cavity are prolonged into the bases of the cusps in the molar and premolar teeth, and in the incisors also there are similar slight prolongations of the cavity towards the angles of the crown.

The **roots** of the teeth are embedded in the sockets or **alveoli** of the jaws, to which they are accurately adapted, and firmly united (Fig. 649) by a highly vascular layer of connective tissue—the **alveolar periosteum** (alveolo-dental periosteum or root-membrane). This is attached to the wall of the alveolus on the one hand and to the root of the tooth on the other, whilst above it is continuous with the connective tissues of the gum.

So accurately are the root and the alveolus adapted to each other over their whole extent, and so firmly does the periosteum bind them together, that, under normal conditions, the tooth is quite firmly fixed in the bone, and no movement of the root within the alveolus can take place; the vessels and nerves entering at the apex are thus secured against pressure or strain.

When, however, the alveolar periosteum is inflamed it becomes swollen and exquisitely sensitive; the tooth, as a result of the swelling, is pushed partly out of its socket, its crown projects above those of its neighbours, and strikes against the opposing tooth when the mouth is closed, giving rise to much pain and discomfort.

The **neck**, although a useful term, can scarcely be recognised as a distinct constriction in the permanent teeth; it corresponds to the line along which the gum and alveolar periosteum meet, or along which the gum is united to the tooth; but, as already pointed out, the gum does not stop at the neck, but forms a free fold which surrounds the base of the crown collar-wise for a short distance. The outline of the margin of the gum opposite the labial and lingual surfaces of the crown is usually concave, but opposite the proximal and distal sides of the tooth it is convex, and reaches much nearer to the edge of the crown than on the other surfaces.

In the incisors and canines the **pulp cavity**, which is about $\frac{1}{3}$ to $\frac{1}{4}$ the diameter of the tooth, passes very gradually into the root canal (Fig. 649), so that it is difficult to say where one ends and the other begins. The reverse is the case in the molars, whilst the premolars are somewhat variable in this respect.

Tartar is a hard calcareous deposit from the saliva (salivary calculus), often found on the teeth near their necks. It is composed of lime salts, and its deposit is largely determined by the presence of organisms (leptothrix, etc.) in the mouth.

THE PERMANENT TEETH.

The permanent teeth (Figs. 650 and 655) are thirty-two in number, sixteen above and sixteen below, or eight in each half of either jaw; and, although we can group them under four heads—incisors, canines, premolars, and molars—the individual teeth differ so much in their characters that each tooth will require a separate description.

Descriptive Terms.—Before describing the permanent teeth, it will be well to explain certain terms used to denote the surfaces of the teeth, a matter of some importance, seeing that the terms inner and outer, anterior and posterior, cannot, owing to the curvature of the dental arches, be properly applied to all the teeth in the same sense. For this reason the terms given below have been adopted as being free from misconception.

The part of a tooth which comes in contact with the teeth of the opposite jaw is known as the **grinding** or **masticating surface** (facies masticatoria, Fig. 652). The surface in contact with or looking towards its predecessor in the row is known as the **proximal surface** (*facies medialis* in incisors and canines, *facies anterior* in premolars and molars); the opposite surface, namely, that which looks towards its successor in the row, is known as the **distal surface** (*facies lateralis* in incisors and canines, *facies posterior* in molars and premolars). The surface which looks towards the tongue is the **lingual surface** (facies lingualis), and that looking in the opposite direction, *i.e.* towards the lips and cheek, the **labial surface** (facies labialis). The portion of a tooth which touches its neighbour in the same row is known as the **contact surface** (facies contactus).

Incisor Teeth (dentes incisivi, Figs. 650 and 651).—These teeth, four in number in each jaw, are used specially for cutting the food, hence their name. The **crown** of each is chisel-shaped, and presents an anterior or labial surface which is convex in all directions, a posterior concave surface, and a chisel-like edge, which, when first cut, is surmounted by three small tubercles separated by two grooves. These tubercles, however, are soon worn down, and the edge becomes straight or nearly so. Owing to the fact that the upper incisors overlap those in the lower jaw, the cutting edge is worn away, or bevelled, on the posterior aspect in the former, but on the anterior aspect or summit in the latter. The upper, but particularly the upper central incisors, are of large size, and slope somewhat forwards; whilst the

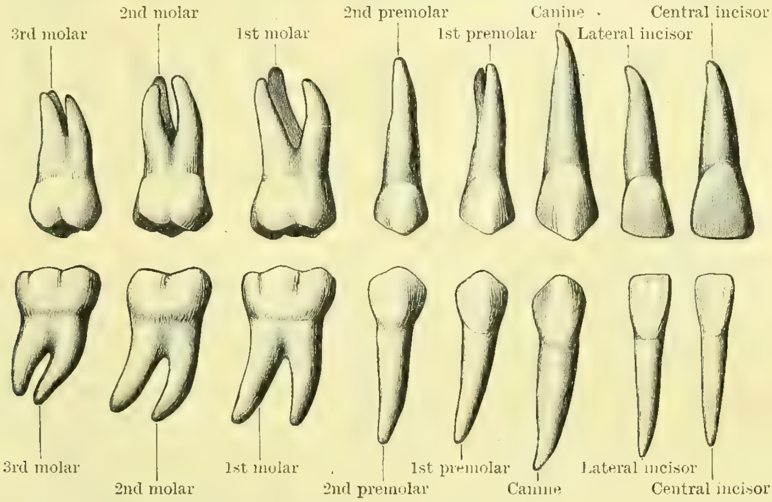


Fig. 650.—The Permanent Teeth of the Right Side, Outer or Labial Aspect.

The upper row shows the upper teeth, the lower row the lower teeth. The wide vertical "labial ridge" is distinct on the upper canine and premolar teeth.

lower incisors, which are all nearly equal in size, are much smaller—being the smallest of all the teeth—and are placed vertically. The roots of the incisors are single, though a groove is occasionally seen on each side, suggesting a division.

The central upper incisors are very much larger than the upper lateral incisors (Fig. 650), but in the lower jaw the opposite is the case, the lateral incisors being slightly the larger. In all incisors the outer (distal) angle of the crown is more rounded than the proximal. The posterior concave surface of the crown in the upper incisors is usually limited towards the gum by a Λ-shaped ridge (Fig. 651), known as the **basal ridge** or **cingulum.** The two limbs of the Λ are continued up along the sides of the posterior surface, whilst the apex is turned towards the gum; and here, particularly in the lateral incisor, there is often developed a small **lingual cusp** (Fig. 651). The cingulum is rarely found on the lower incisors.

The roots of the upper incisors and canines are conical and rounded (the laterals and canines not so distinctly as the centrals, Fig. 654), whilst those of the lower jaw are flattened from side to side (proximo-distally).

Canine Teeth.—In the four canine teeth (dentes canini), which succeed the incisors in each row (Figs. 650 and 651), the **crown** is large and conical, corresponding closely in general form to a very large central incisor with its angles cut away, so that the crown assumes a pointed or conical shape. The labial surface is convex, the lingual usually somewhat concave. The root is single and long, particularly in the upper canine, the root of which is longer than that of any other tooth, and produces the canine eminence on the anterior surface of the upper jaw. The upper canines are larger than the corresponding lower teeth, behind which they bite; and they are sometimes known as the "eye teeth."

The upper canine presents on its lingual surface a well-marked cingulum, and often a distinct lingual cusp; in addition, there is usually a median ridge running from the point of the crown to the apex of the cingulum, which is separated from the lateral part of the cingulum on each side by a slight depression. These points are neither so well marked, nor so constant, in the lower as in the upper canine.

Of the two margins sloping away from the apex of the crown, the lateral is the longer in both teeth. After it has been a little worn the lower canine is less distinctly pointed than the upper;

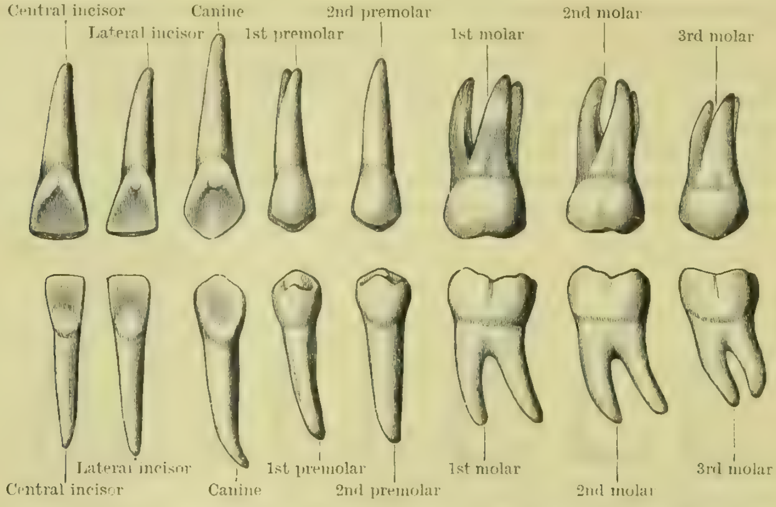


FIG. 651.—THE PERMANENT TEETH OF THE RIGHT SIDE, INNER OR LINGUAL ASPECT.

The upper row shows the upper teeth, the lower row the lower teeth. The cingulum is distinct on the upper incisors and both canines, the lingual cusp on the upper lateral incisor and the upper canine.

its root is also more flattened. On the labial surface of the crown, of both canines and premolars, a wide low vertical ridge (labial ridge) can generally be made out (Fig. 650); it is most distinct on the canine and first upper premolar.

Premolar or Bicuspid Teeth (dentes premolares, Figs. 650 and 651).—Eight in number, two in each jaw above and below, the premolar teeth are placed behind the canines, and in front of the molars as indicated by the term "premolar." The **crown**, which, unlike that of the incisors and canines, is flattened from before backwards (proximo-distally), is characterised by the presence of two cusps (Fig. 652), hence the term bicuspid often applied to these teeth. One of the cusps, the larger, is placed on the outer or labial, the other on the inner or lingual side. The labial and lingual surfaces are both convex. The **root** is single, but it is, as a rule, flattened from before backwards (proximo-distally) and grooved, showing in this a tendency to division, which often actually takes place in the first upper premolar. The upper premolars are easily distinguished by the fact that their two cusps are large and are separated from one another by a distinct antero-posterior fissure (Fig. 652); whilst in the lower premolars, on the other hand, the separation between the two cusps is not effected by a continuous fissure as in the upper teeth, but by two dimple-like depressions separated by a ridge, which joins the two cusps (Fig. 653). In the upper premolars, therefore, the two cusps are separated by a fissure, in the lower they are united by a ridge.

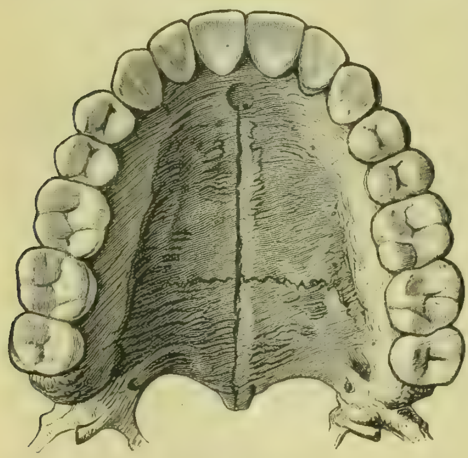


FIG. 652.—THE UPPER PERMANENT TEETH, viewed from below.

The cusps of the premolars and molars of the right side (left of picture) are particularly well shown. The ridge from the inner anterior (proximo-lingual) to the outer posterior (labio-distal) cusp is also distinct in the first and second molars. The second molars show four cusps, one of them small, although three only are frequently found.

The first upper premolar is often slightly larger than the second; the reverse is the case in the lower jaw. The outer or labial surface of the crown is usually somewhat larger than the

inner or lingual surface in all premolars. The upper are distinguished from the lower bicuspids, as pointed out above, by the fact that in the upper the two cusps are separated by a groove, in the lower they are united by a ridge; in the latter also the crowns are more circular (Figs. 646 and 653). It will further usually be found that the outer or labial surface of the crown is strongly sloped (bevelled) inwards, near the grinding surface, in the lower premolars. The first can usually be distinguished from the second by the fact, that, while the lingual cusp and surface are smaller than the labial in the first premolar, they are nearly of the same size in the second. In addition, the root of the first upper premolar is bifid or nearly so, and its labial ridge is fairly distinct, but is indistinct in the second. In the first lower premolar the lingual cusp and surface are very small, in fact the cusp is quite rudimentary. It should, however, be added that it is often extremely difficult to identify the various bicuspids. The differences may be expressed in tabular form thus:—

Premolars.

		Root.	**Cusp and Surface.**
Upper (have two cusps separated by a groove)	1st premolar	bifid, or nearly so	Lingual smaller than labial.
	2nd ,,	single	Lingual nearly as large as labial.
Lower (have two cusps united by a ridge)	1st premolar	single	Lingual much smaller than labial.
	2nd ,,	,,	Lingual nearly as large as labial.

Molar Teeth (dentes molares).—The molar teeth, also known as the **grinders** or **multicuspidati**, are twelve in number—three on each side above and below—and are distinguished as first, second, and third molars. The latter is also known as the wisdom tooth, owing to its late eruption. All the molars are characterised by the large size of the crown and the possession of three or more trihedral cusps on the masticating surface (Figs. 652 and 653). They are the largest of all the teeth, but they diminish in size from the first to the third, the last being, as a rule, the smallest of the three. In shape the crown is more or less quadrangular, with convex labial and lingual surfaces. The roots are either two or three in number, but frequently in the wisdom teeth they are united to a varying degree.

The molars of the upper and lower jaws differ so considerably in their further details that they must be considered separately. They may be most readily distinguished from one another by the fact that normally the **upper molars** possess three roots (Figs. 650 and 651), whilst the **lower molars** have two at most. The number of cusps, though not so reliable a guide as the form of the root, is also generally sufficient to distinguish them. In the upper molars there are either three or four cusps, whilst in the lower the number is most commonly five (see, however, page 971).

In the **upper molars**, the **crown**, viewed from the grinding surface (Fig. 652), is rhomboidal in shape (*i.e.* quadrangular with the angles not right angles). The outer (labial) and the inner (lingual) surfaces are convex. The number of **cusps** is either four or three. On the *first* there are invariably four—two on the labial and two on the lingual side—the antero-internal (proximo-lingual) of these being connected with the postero-external (labio-distal) by an oblique ridge (Fig. 652), which is also found on the *second* and *third* molars when these bear four distinct cusps. The *second* upper molar has either four or three cusps in about an equal proportion of European skulls, whilst in the third the number is much more frequently three than four. The **roots** in the upper molars are three in number (except, occasionally, when the three roots of the wisdom tooth are confluent), two being external or labial, and the third internal or palatal (Figs. 650, 651, and 654).

In the **lower molars** the **crown**, viewed from above (Fig. 653), is somewhat cubical. The outer and inner surfaces are convex, as in the upper molars. The *first*, as a rule, bears five cusps, two being on the outer side, two on the inner, and the fifth behind and external, that is, between the two posterior cusps and somewhat to the outer side. The *second* has usually only four cusps; a fifth, however, is sometimes present. The *third* has either four or five, the former number more frequently than the latter.

The **roots** of the lower molars are two in number, each wide, grooved, and

flattened from before backwards. One is placed anteriorly, the other posteriorly, and both are usually recurved in their lower portions (Fig. 650). As in the corre-

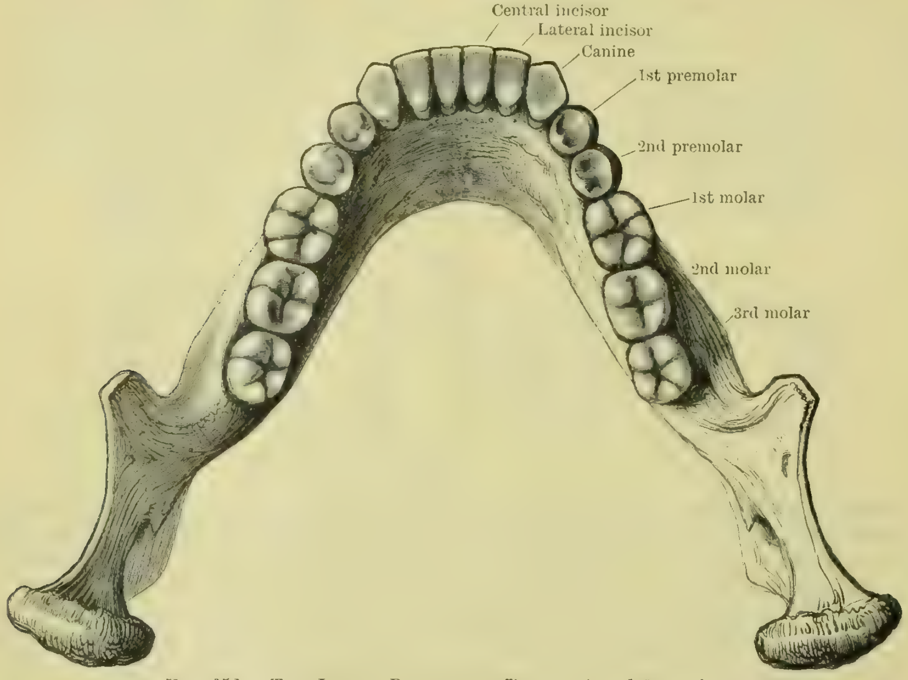


FIG. 653.—THE LOWER PERMANENT TEETH, viewed from above.

sponding teeth of the upper jaw, the roots of the lower wisdom teeth are often more or less united into a single mass.

The chief characters of the upper and lower molars may be summarised thus :—

Molars.

		1st Upper.	2nd Upper.	3rd Upper.
Upper	Cusps	4	3 or 4	3 or 4
	Roots	3	3	3 (or 1)
		1st Lower.	**2nd Lower.**	**3rd Lower.**
Lower	Cusps	5	4 or 5	4 or 5
	Roots	2	2	2 (or 1)

The molars diminish in size from before backwards. This remark applies particularly to the wisdom teeth, which are extremely variable in form and position among civilised races. The long axis of the upper molars has a general direction downwards and outwards; whilst that of the lower molars, which the former partly overlap, slopes upwards and inwards, with the result that the outer cusps of the lower molars lie in the groove separating the inner from the outer cusps of the upper teeth (Fig. 637, p. 946). As a further result of this overlapping, the outer edge of the crown is sharp and the inner edge rounded in the upper molars; whilst the inner edge is sharp and the outer edge rounded in the lower set. The cause of this is obvious. The outer margins of the upper molars overlap their fellows on the buccal side, whilst the inner margins of the lower molars overlap their fellows on the lingual side; these margins, therefore, are subject to comparatively little attrition, and consequently remain sharp. The other margin of each tooth, on the other hand, strikes against the groove on the crown of the opposing tooth, and consequently becomes worn and round.

The fissures which separate the cusps on the grinding surfaces of the molar teeth are generally continued as faint grooves on the labial and lingual surfaces.

Upper Molars.—The crowns, as already stated, are rhomboidal in shape, and when viewing their grinding surfaces, as in Fig. 652, if the planes of separation between them be prolonged, they would strike the middle line near the back part of the hard palate; in other words, their

proximal and distal surfaces are not in transverse but in oblique planes, sloping strongly backwards and inwards, and converging somewhat internally. A knowledge of this is useful in determining the side to which an upper molar belongs, as is the fact that the anterior labial root is broader than the posterior (Fig. 654).

As regards the *number of cusps* (Fig. 652):—The first upper molar has four cusps in practically all skulls (99 per cent); occasionally, indeed, another, but very rudimentary, cusp is present on the lingual side of the antero-internal (proximo-lingual) cusp. The second molar has either three or four in an almost equal proportion of Europeans, but more frequently four taking the teeth of all nations together. (According to Topinard, four cusps are present in 66 per cent of all races, and in 58 per cent of European, Semitic, and Egyptian skulls; according to Zuckerkandl, in 73·5 per cent of the lower races and 45·6 per cent of Europeans). The third upper molar has three cusps much more frequently than four amongst Europeans (four cusps only in 36 per cent, although it has four cusps more frequently in certain lower races). It should be remarked that, while there are practically always four cusps in the first molar, still there is a tendency to the disappearance of the postero-internal (disto-lingual) cusp, which tendency grows more pronounced as we pass backwards to the second and third molars. The other cusps are practically constant.

The three **roots** of the upper molars (Figs. 650, 651, and 654) are a large inner or palatal, sub-cylindrical in shape, and two external or labial roots, smaller and flattened from before backwards. The palatal fang, which is placed opposite the posterior labial root, is often united to one of the others. The lower part of the antrum of Highmore generally extends down between the palatal and the two labial fangs (Fig. 637, p. 946), but the latter project on its floor more frequently than the palatal root. In the wisdom tooth the three roots are frequently more or less united into a single conical process (Fig. 654).

Lower Molars.—The **crowns** are more massive than those of the upper molars, and are elongated antero-posteriorly (Fig. 653). A crucial groove separates the four chief cusps from one another; this bifurcates behind to enclose the fifth cusp, which lies slightly to the outer side of the middle of the tooth. The *number of cusps* present in the lower molars is as follows:—The first has usually five cusps (62 per cent of all races, 61 per cent of Europeans); the second has four cusps, as a rule (five cusps in only 24 per cent of all skulls); the lower wisdom tooth has four cusps a little more frequently than five (five in 46 per cent of all skulls), but like the upper wisdom tooth it is extremely variable.

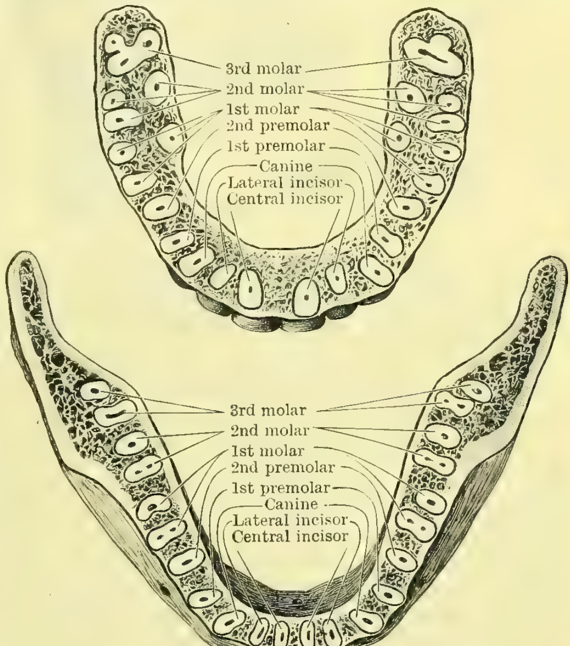


FIG. 654.—HORIZONTAL SECTIONS THROUGH BOTH THE UPPER AND LOWER JAWS to show the roots of the teeth. The sections were carried through the bones a short distance from the edge of their alveolar borders. The upper figure shows the upper teeth, the lower figure the lower teeth. Note the flattened roots of the lower incisors, the two root canals in the anterior root of each lower molar, and the confluence of the three roots of the upper wisdom teeth.

The **roots** of the lower molars (Fig. 650), two in number, are flattened from before backwards, and very wide. The anterior of these has two root canals; the posterior but one (Fig. 654). The wisdom tooth has commonly two roots like its fellows; occasionally the two are united. In determining the side to which a lower molar belongs, it should be remembered that the lower part of the root is generally curved backwards, and also that the blunter margin of the crown (see above) and the fifth cusp, if present, are on the outer side.

Arrangement of the Teeth in the Jaws.—The teeth are arranged in each jaw in a curved row—the **dental arch** (arcus dentalis)—of approximately a semi-oval form (Figs. 652 and 653). The curve formed by the upper teeth, however, is wider than that formed by the lower set, so that when the two are brought in contact the upper incisors and canines overlap their fellows in front, and the outer cusps of the upper premolars and molars overlap the corresponding cusps of the lower teeth (Fig. 637, p. 946). It will also be seen that, as a rule, the teeth in one jaw are not placed exactly opposite their fellows, but rather opposite the interval between two teeth, in the other jaw (Fig. 655). This arrangement is brought about largely by the great width of the upper central incisors as compared with

their fellows of the lower jaw, which throws the upper canines and the succeeding teeth into a position behind (distal to) that of the same named teeth of the lower set. But as the lower molars are larger in their antero-posterior diameter than those of the upper row—and this remark applies particularly to the wisdom teeth—the two dental arches terminate behind at approximately the same point.

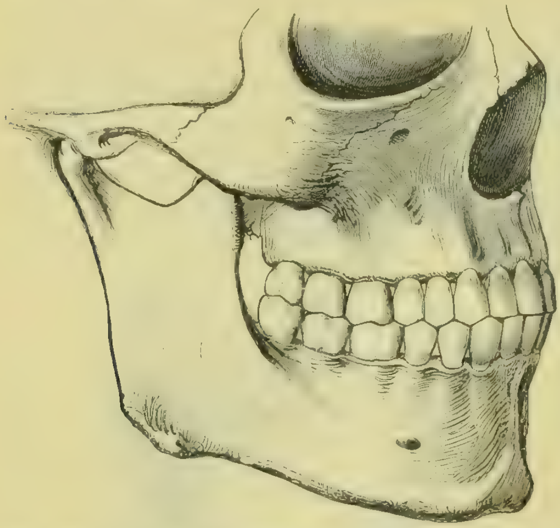


FIG. 655.—To show the relation of the upper to the lower teeth when the mouth is closed. The manner in which a tooth of one row usually strikes against two teeth of the opposite row, and the resulting interlocking of the teeth, is to be noted.

The upper dental arch is said to form an **elliptical**, the lower a **parabolic curve** (Figs. 652 and 653). The line formed by the grinding surfaces of the upper teeth, as seen on profile view (Fig. 655), is usually somewhat convex, owing largely to the failure of the wisdom tooth to descend into line with the others. Similarly the line of the lower teeth is as a rule concave.

In both jaws the crowns of the front teeth are higher (longer) than those of the molars.

Period of Eruption of the Permanent Teeth.—Although there is considerable variety in the *dates* at which the various permanent teeth appear above the gums, the *order* of eruption is practically constant in different individuals, and is as follows:—Before any of the temporary teeth are lost the first permanent molars appear behind the 2nd milk molars. Next the central milk incisors fall out, and their places are taken by the permanent teeth of the same name; then follow the remaining teeth in the following order: Lateral incisors, 1st premolars, 2nd premolars, canines, 2nd molars, and 3rd molars. It will be observed that the eruption of the canine is delayed until the two premolars, which succeed it in the row, are cut, so that it breaks the otherwise regular order of eruption. The 1st molar is sometimes popularly known, owing to the date of its eruption, as the "six-year-old tooth," and the 2nd molar as "the twelve-year-old tooth."

The dates at which the eruption usually takes place may be simply stated as follows for the lower teeth; those of the upper jaw appear a little later:—

1st molars appear soon after the 6th year.					
Central incisors	appear	soon after the	7th	year.	
Lateral	,,	,,	8th	,,	
1st premolar	,,	,,	9th	,,	
2nd ,,	,,	,,	10th	,,	
Canine ,,	,,	,,	11th	,,	
2nd molar	,,	,,	12th	,,	
3rd ,,	,,	from the	17th	,,	to

THE MILK TEETH.

The **deciduous**, **temporary**, or **milk teeth** (dentes decidui) are twenty in number, ten above and ten below, or five in each half of each jaw—namely, two incisors, one canine, and two molars. They may be distinguished from the permanent teeth by their smaller size, their well-marked and constricted necks, and, in the case of the molars, by the wide divergence of their roots (Fig. 656). Otherwise they correspond so closely to the same named teeth of the permanent set, that they require no separate description, except in the case of the molars. The first upper molar has but three cusps on its crown—two external and one internal; the first lower molar has four—two external and two internal, and the crowns of both

are flattened from side to side. The second molars of the upper jaw have four, those of the lower jaw five cusps each. In every case the second are much larger than the first molars. The cusps are sharper and are separated by deeper fissures or fossæ than those of the permanent teeth, whilst the roots of the milk molars, except for their greater divergence, agree with those of the permanent set.

The marked constriction at the neck of the milk teeth (Fig. 656) is due to a great thickening of the cap of enamel on the crown, and its abrupt termination as the neck is reached. The enamel, too, is much whiter as a rule than in the permanent teeth. It should be added that the labial surface of the canines and molars departs very markedly from the vertical; it slopes strongly inwards towards the mouth cavity as it approaches the grinding surface of the crown, which latter is, as a result, much reduced in width.

The divergence of the fangs in the milk molars allows the crowns of the permanent premolars to fit in between them before the milk molars are shed.

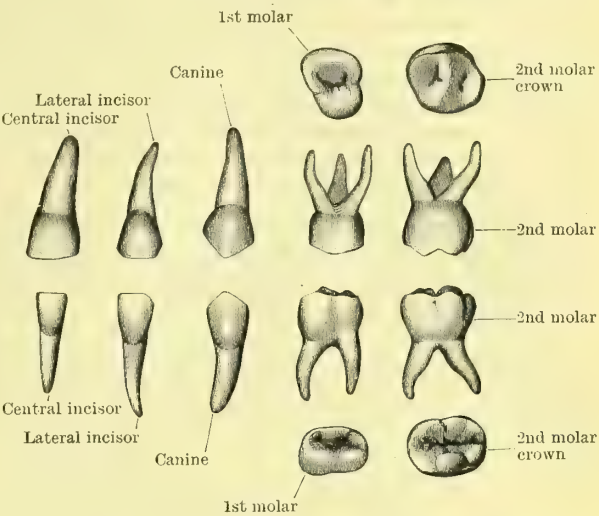


Fig. 656.—The Milk Teeth of the Left Side.

The masticating surfaces of the two upper molars are shown above. In the second row the upper teeth are viewed from the outer or labial side. In the third row the lower teeth are shown in a similar manner; and below are the masticating surfaces of the two lower molars. In the specimen from which the first upper molar was drawn the two outer or buccal cusps were not distinctly separated, as is often the case.

Structure of the Teeth.

As mentioned above, the teeth are composed of three special tissues, enamel, dentine, and crusta petrosa, in addition to the pulp which occupies the tooth cavity. The chief mass of the tooth is formed of dentine, which surrounds the pulp cavity and extends from crown to root; outside this is a covering of enamel on the crown, and a layer of crusta petrosa or cement on the root.

The **enamel** (substantia adamantina) is the dense, white, glistening layer which forms a cap, thickest over the cusps, for the portion of each tooth projecting above the gum (Fig. 649). At the neck it ceases gradually, being here slightly overlapped by the crusta petrosa.

It is composed chiefly of phosphate and carbonate of lime (phosphate of calcium 89·82 per cent, carbonate of calcium 4·37 per cent, magnesium phosphate 1·34 per cent, a trace of calcium fluoride, other salts ·88 per cent), and has generally been considered to contain about 3·6 per cent of organic substance; but this Tomes has recently shown to be inaccurate: "That which has heretofore been set down as organic matter is simply water combined with the lime salts. Enamel is to be regarded as an inorganic substance composed of lime salts, which have been deposited in particular patterns and formed under the influence of organic tissues, which have themselves disappeared during its formation."

Enamel consists of calcified microscopic prisms (prismata adamantina), radiating from the surface of the dentine, on which their inner ends lie, to the surface of the crown, on which they terminate by free ends. These prisims are hexagonal in shape, solid, and of considerable length, for most of them reach from the dentine to the surface of the crown without interruption. The prisms, which are calcified themselves, are held together by the smallest possible amount of calcified matrix (Tomes). In old teeth the cap of enamel is often worn away over the cusps, the dentine is then exposed, and is easily recognised by its yellowish colour, which contrasts strongly with the whiteness of the enamel.

Whilst adjacent enamel prisms are in general parallel to one another, they do not usually take a straight, but rather a wavy course, and in alternate layers they are often inclined in opposite directions, thus giving rise to certain radial striations seen by reflected light (Schreger's lines). Certain other pigmented lines, more or less parallel to the surface, are also seen in the enamel (brown striæ of Retzius). They are due to true pigmentation (Williams), and mark the lines of deposit of the enamel during its development. The enamel prisms are more or less tubular in certain animals—viz. in all marsupials except the wombat, in the hyrax, certain insectivora, and certain rodents.

Nasmyth's membrane (enamel cuticle) is an extremely thin ($\frac{1}{20000}$ of an inch) cuticular layer which covers the enamel of recently-cut teeth, and is very indestructible, resisting almost all re-agents. Two chief views are held as to its origin. One that it is the last formed layer of enamel, which has not yet been calcified, and therefore the final product of the enamel cells. The other that it is produced by the outer layer of cells of the enamel organ. This latter seems to be the more probable view.

Dentine (substantia eburnea) is the hard and highly elastic substance, yellowish white in colour, which forms the greater part of the mass of every tooth (Fig. 657). Like the enamel it is highly calcified, but it differs from enamel in containing a very considerable amount of organic matter and water incorporated with its salts, which are chiefly phosphate and carbonate of lime.

Fresh human dentine contains 10 per cent of water, 28 per cent of organic and 62 per cent of inorganic material. The organic matter is composed chiefly of collagen, and to a less extent of elastin. The inorganic matter consists of (1) calcium phosphate (with a trace of fluoride), (2) calcium carbonate, and (3) magnesium phosphate, the percentages present in dried dentine being 66·72, 3·36, 1·08 respectively.

Dentine consists of a highly calcified organic matrix, which is itself practically structureless, although everywhere traversed by tubes—the **dentinal tubes**—which give to this tissue a finely striated appearance, the striæ usually running in wavy lines. The dentinal tubes begin by open mouths on the wall of the pulp cavity, whence they run an undulating, and at the same time a somewhat spiral course, towards the periphery of the dentine. They give off fine anastomosing branches, and occasionally divide into two. Somewhat reduced in size, they usually end in the outer part of the dentine.

The tubules are generally described as being lined by special sheaths (dentinal sheaths of Neumann) which are composed of a most resistant material, and possibly are calcified. It should be mentioned that the presence of these sheaths as separate structures is doubted by some authorities, who hold that the part described as the sheath is only a modified portion of the dentinal matrix surrounding the tubules.

The dentinal tubules are occupied by processes, prolonged from the outermost cells of the pulp—the odontoblasts. These processes are called after their discoverer, **Tomes' fibrils** (dentinal fibrils), and they are probably sensory in function.

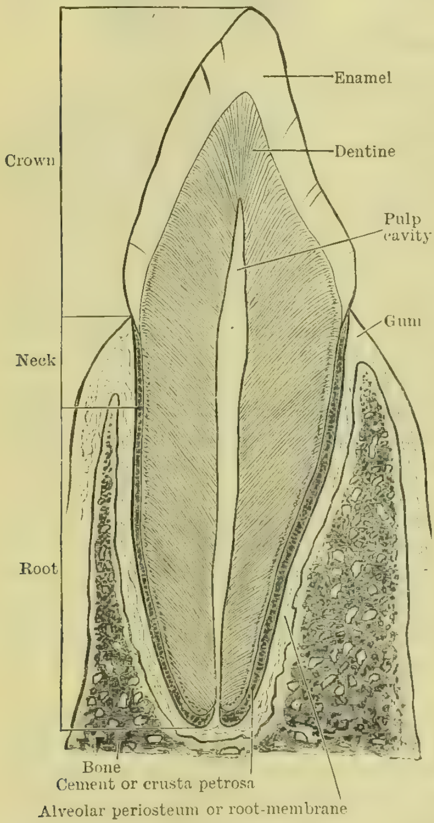


FIG. 657.—VERTICAL SECTION OF CANINE TOOTH, to illustrate its various parts, and its structure.

The concentric **lines of Schreger**, frequently seen in the dentine, are due to bends in successive dentinal tubes taking place along regular lines parallel to the periphery of the dentine. Other lines (the incremental lines of Salter), due to imperfect calcification, are found arching across the substance of the dentine, chiefly in the crown. There must also be mentioned the **interglobular spaces**, intervals left in the dentine, as a result of imperfect calcification, bounded by the fully calcified surrounding dentine, the contour of which is in the form of a number of small projecting globules of dentine. These interglobular spaces are very numerous in the outer or "granular layer" of the dentine, particularly beneath the cementum (see Fig. 649).

The **crusta petrosa** or **cementum** (substantia ossea) is a layer of modified bone which encases the whole of the tooth except its crown. It begins as a very thin stratum, slightly overlapping the enamel at the neck. From this it is continued, increasing in amount, towards the apex, which latter is formed entirely of this substance. It is relatively less in amount in the child, and increases during life. In places the dentine seems to pass imperceptibly into the crusta petrosa (the "granular layer" of dentine marking the

junction of the two, see Fig. 649), and some of the dentinal tubes are continuous with the lacunæ of the cementum. Like true bone, it is laminated, it possesses lacunæ, canaliculi, and, when in large masses, it may even contain a few Haversian canals.

The **tooth pulp** occupies the pulp cavity and the root canals of the teeth. It is composed of a number of branched connective tissue cells, the anastomosing processes of which form a fine connective tissue network, containing in its meshes a jelly-like material, in addition to numerous vessels and nerves, but no lymphatics. The most superficial of these cells form in the young tooth a continuous layer of columnar, epithelium-like cells, lying on the surface of the pulp against the dentine; they are known as **odontoblasts**, for they are the active agents in the formation of dentine. From the outer ends of the odontoblasts processes are continued into the dentinal tubes, where they have been already referred to as Tomes' fibrils. The vessels of the pulp are numerous, and form a capillary plexus immediately within the odontoblasts. The nerves form rich plexuses throughout the pulp, but their exact mode of ending is unknown.

The **alveolar periosteum** (alveolo-dental periosteum or root-membrane) is a layer of connective tissue free from elastic fibres, but well supplied both with blood-vessels and nerves, which fixes the root of the tooth in the alveolus, being firmly united by perforating fibres of Sharpey, to the crusta petrosa on the one hand, and to the bone of the alveolus on the other. It establishes a communication between the bone of the jaw and the cementum, and above it is continuous with the tissue of the gum. Its blood comes chiefly from the arteries, which subsequently enter the apical canals for the supply of the pulp, but in part also from the vessels of the bone and those of the gum (hence the relief obtained in dental periostitis by lancing the gum).

Development of the Teeth.

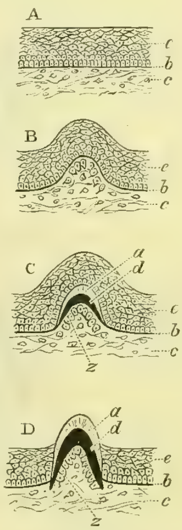
At the beginning of this chapter a tooth was described as a calcified papilla of the mucous membrane, composed of two chief parts—namely, the enamel formed by the epithelial layer, and the dentine by the connective tissue layer of the mucous membrane. The details of the process by which such a tooth is developed from the two layers of the mucous membrane are both numerous and intricate, and can be but briefly described here.

In lower vertebrates (sharks, rays, etc.), teeth which correspond essentially, both in structure and development, to those of mammals, are found on the surface of the body, and are known as **dermal teeth.** The following outline of the development of the dermal tooth of a shark may assist in rendering the development of the human teeth more intelligible:—

First, a **papilla** is formed from the corium or connective tissue layer of the skin (Fig. 658, B), which papilla is covered over by the epithelial layer.

Next the superficial (connective tissue) cells of the papilla begin to form a layer of **dentine** on the surface of the papilla (Fig. 658, C), which it soon encases, the remains of the papilla persisting in the interior as the future **pulp.** At the same time the deepest cells of the epithelium deposit a layer of **enamel**, outside the dentine, over the summit of the papilla (Fig. 658, C), and subsequently the two—enamel and dentine—become inseparably united, thus giving rise to the substance of the tooth.

At a later period the epithelium covering the summit disappears and the tooth comes to the surface: this constitutes its **eruption** (Fig. 658, D).



A, Section of skin showing epithelium e, basement membrane b, and connective tissue layer c.

B shows the papilla of the connective tissue layer growing up covered by the epithelial layer.

In C the superficial cells of the papilla z begin to deposit dentine d over the papilla, and at the same time the deepest cells of the epithelium deposit enamel a.

D shows the tooth breaking through the epithelium and reaching the surface.

Fig. 658.—Diagram to illustrate the Development of a Dermal Tooth in the Shark.

In all figures—*a*, enamel; *b*, basement membrane; *c*, connective tissue layer of skin; *d*, dentine; *e*, epithelium; and *z*, superficial cells of papilla.

In the case of the mammalian tooth a similar process takes place, not, however, on the surface, but deep down in the substance of the gum, into which a downgrowth of epithelium has previously taken place. This epithelial downgrowth spreads out in the substance of the jaw, and into it the papilla grows up, and goes through the other changes described above, as if the whole process took place on the surface.

Development of Human Teeth.—The following is a brief summary of the chief events in the development of a human tooth. For convenience in expression and terms,

the description refers to the development of a lower tooth. The upper teeth are of course developed in a manner exactly similar.

1. The first distinct evidence of the development of the teeth is to be found in a thickening of the mouth epithelium, at the site of the future gum, and a resulting downgrowth of its deeper portion into the substance of the primitive jaw (Fig. 659, I.). This epithelial downgrowth is continued along the whole length of the gum, and is known as the **dental lamina** or **tooth-band** (Zahnleiste). On the under surface of the dental lamina there soon appears a series of knob-like projections—one for each of the milk teeth (Fig. 659, II.)—which are known as **enamel germs** or **enamel organs**. These enamel organs are connected with the epithelium of the dental lamina by a constricted part, and although at first knob-like, they soon become bell-shaped owing to the invagination of the lower surface of the knobs, so that each may now be compared to an inverted egg-cup.

I. Shows the downgrowth of the dental lamina D.L from the surface epithelium E and the beginning of the enamel germ E.G.

II. Shows the further growth of the enamel germ and its invagination.

III. The enamel germ is more invaginated, and its inner layer of cells becomes columnar. A, the dental lamina, grows thinner, but near its posterior or lingual edge there is an enlargement R.G which is the reserve germ for a permanent tooth. The superficial cells of the dentine papilla P are becoming columnar.

IV. The inner columnar cells of the enamel germ (called enamel cells) A have formed a cap of enamel En, inside which the superficial cells of the papilla, the odontoblasts O, have formed a layer of dentine D.

V. Shows a more advanced stage still. The deposit of dentine is extending downwards, and enclosing the papilla to form the future pulp, in which a vessel V is seen.

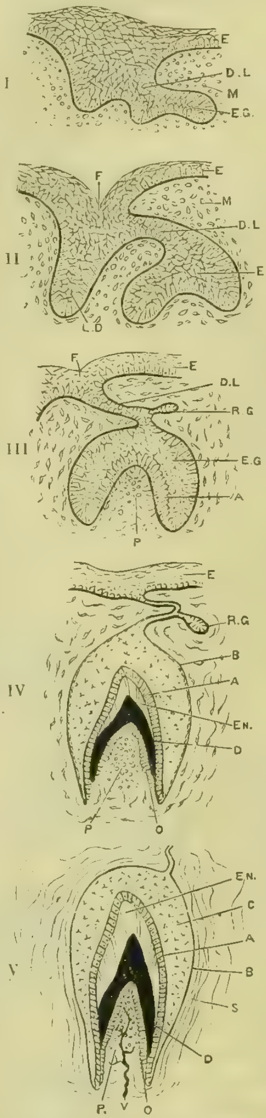


FIG. 659.—DIAGRAM TO ILLUSTRATE DEVELOPMENT OF A TOOTH.

A, Inner layer of enamel germ; B, Outer layer; C, Remains of intermediate cells; D, Dentine; D.L, Dental lamina; E, Epithelium; E.G, Enamel germ; En, Enamel; F, Dental furrow; L.D, Labio-dental furrow; M, Connective tissue cells; O, Odontoblasts; P, Dentine papilla; R.G, Reserve germ; V, Blood-vessel.

2. As soon as the enamel organs begin to assume a cup-like shape, the cellular connective tissue of the jaw beneath grows up and projects into the cavity of the cup (Fig. 659, III.) in the form of a papilla—the **dentine papilla** (papilla dentis). The arrangement, pursuing our simile, may now be compared to an egg fitting into its cup—the dentine papilla representing the egg, and the enamel organ the cup (Fig. 659, III.).

3. The two layers of cells which are thus brought in contact, namely, the epithelial cells lining the concavity of the enamel organ, and the superficial cells of the dentine papilla, become elongated or columnar, and undergo other changes, preliminary to the production of the enamel by the former—which are now called **enamel cells** or **ameloblasts**—and the dentine by the latter, which are known as **odontoblasts**.

4. The **odontoblasts**, that is the layer of columnar-shaped connective tissue cells lying on the surface of the dentine papilla, begin to form at their outer ends a layer of **dentine** (Fig. 659, IV.). Similarly, the enamel cells lining the cup begin to form at their inner surface a layer of **enamel** on the top of the layer of dentine (Fig. 659, IV.), to which it adheres: in each case the deposit taking place first at the summit of the tooth.

5. The formation of dentine and enamel proceeds apace, the dentine increasing at the expense of the papilla, the enamel similarly encroaching on the cup or enamel organ; and in each case the two layers of cells—odontoblasts and enamel cells—which produced the deposits, retiring gradually from one another, as the space between them becomes occupied by the newly-formed dentine and enamel respectively (Fig. 659, V.).

The remains of the dentine papilla persist as the **pulp** of the tooth, which is covered even in the adult by the odontoblasts, and occupies the **pulp cavity**, *i.e.* the central part of the tooth to which the dentine formation has not extended.

6. Turning now to the jaw itself: The connective tissue of the gum surrounding the **tooth germ** (as the developing tooth with its enamel organ and dentine papilla are called) early becomes condensed and vascular (Fig. 659, V.), and later on forms a membranous bag—the **tooth sac** or **follicle**—which completely shuts off the developing tooth from the surrounding structures. On the floor of this sac the tooth germ sits, the base of its dentine papilla being continuous with the tissue of the floor of the sac, and the young tooth being enclosed by the sac, as a kernel is enclosed by its shell.

7. Reverting to the tooth: When the crown is completed the deposit of dentine, but not of enamel, is continued downwards to form the **root**. This latter is composed chiefly of dentine continuous above with that of the crown, and like it formed by the odontoblasts of the dentine papilla. As the dentine is deposited, and the root is being built up, the connective tissue of the tooth sac comes to surround the root more closely, and deposits on its surface, after the manner of a periosteum, a layer of bone, the **cementum** or **crusta petrosa**. The cementum having been formed, the connective tissue of the sac then persists as the **alveolar periosteum**. The development of the root takes place very slowly, and its lower end is not completed as a rule for some time after the eruption of the tooth has taken place.

8. During the development of the teeth the ossification of the jaw has being going on, and as it grows up on each side, the young teeth, enclosed in their tooth sacs, come to lie in an open bony groove, which is subsequently divided by septa into compartments—the **alveoli**—for the individual tooth sacs. The bone continuing to grow after birth, these compartments become more perfect, but are never entirely closed in over the crowns of the teeth. During the eruption of the teeth the upper and anterior part of these bony cells is absorbed; subsequently, however, it is reformed around each tooth when it has taken its final position.

9. **Eruption.**—Long before the root is completed, the crown, by some force which is not properly understood, but which does not seem to depend on additions to the root, is pushed through the top of the tooth sac, and—the upper and anterior wall of the roomy alveolus having been absorbed at the same time—onwards through the gum until the mouth is reached. Later on, when the tooth has assumed its final position, the alveolus, as already stated, is reformed, and closely embraces the completed root.

10. After the enamel organs of the milk teeth have been formed on the inferior aspect of the dental lamina, as described above, the neck of epithelium by which the lamina is still connected with the surface becomes broken up into a cribriform sheet. Its free posterior border, on the other hand, continues to grow backwards in the tissue of the gum towards the cavity of the mouth (Fig. 659, III. and IV.), and at a later date there appear on its under surface, near the free edge, and behind the several developing milk teeth, the enamel organs—or so-called "reserve germs"—for the corresponding **permanent teeth**, which are developed from these in exactly the same manner as the milk teeth described above.

In connexion with the development of the **permanent molars**, which have no corresponding teeth in the milk set, there takes place a prolongation backwards of the posterior extremity of the dental lamina into the tissue of the jaw, behind the last milk molar. On the inferior aspect of this prolongation, which has no direct connexion with the surface epithelium, enamel organs are formed for the permanent molars, and their further development goes on in the manner described for the other teeth.

The *dates* at which some of the chief events in the development of the teeth occur may be briefly given:—The thickening of the epithelium, the first sign of the future teeth, begins about the sixth week of fœtal life, and the dental lamina is completed by the end of the seventh week.

The dentine papilla for the eight front teeth appear and become surrounded by their enamel organs about the tenth week, and the papilla for the first permanent molar about the seventeenth week.

The first traces of calcification, and the formation of the tooth sacs, takes place about the fifth month of fœtal life.

Eruption of Deciduous Teeth.—The period at which the eruption of the milk teeth takes place is extremely variable, and no two observers seem to agree upon the question. The following, according to Tomes, may be taken as representing the average. The lower central incisors appear first, usually between the sixth and ninth months; then follows a rest of a few months. Next come the four upper incisors, followed by a rest of a few months. Then the lower lateral incisors and the four first molars erupt, succeeded by a rest of a few months. Next appear the canines, and finally the four second molars, which are all cut by the end of the second year.

The following statement is simple, and perhaps is sufficient for all ordinary purposes. The temporary teeth usually appear in the following order:—Central incisors, lateral incisors, first molars, canines and second molars; the eruption commences between the sixth and the ninth month, and is usually completed by the twenty-fourth—the lower teeth, as a rule, preceding the upper.

Formation of Enamel and Dentine.—Different opinions are held as to the method in which the **enamel** is produced by the enamel cells. One view maintains that it is secreted and shed out by the enamel cells (Kölliker). According to the other view, part of the substance of the cells is actually converted or transformed into enamel (Tomes). In connexion with this latter view, which seems to receive more support at present, Tomes has discovered that there projects from the base of each enamel cell, towards or into the most recently formed enamel, a fibrillar process, which has received the name of **Tomes' process**, and he holds that the enamel is formed by calcification taking place in or around the process.

Similarly, two views are held as to the production of **dentine** by the odontoblasts; one, that the odontoblasts secrete the matrix of the dentine, and the other, that their substance is actually converted into the matrix. The odontoblasts, when active, are branched columnar-shaped cells, and from their outer ends one or more processes extend towards and into the dentine; between these processes a matrix appears—produced probably by the odontoblasts—and soon this matrix becomes calcified. In this way the dentine is formed, and the process is repeated until its full thickness is attained. The branches of the odontoblasts, encased in dentine, just mentioned, are the Tomes' fibrils already described; the canals in which they lie are the dentinal tubes; and the fibrils themselves are concerned in the production of the sheaths of Neumann which line the tubes.

The **tooth-sacs,** when fully developed, are large and distinct fibrous bags which lie in the alveoli of the maxilla and are continuous above with the tissue of the gum. On the lingual side of the sacs of the milk teeth are found the germs of the permanent teeth, surrounded by their own sacs. These latter are at first very small, and are partly embedded in the posterior wall of the temporary tooth-sacs, but subsequently they come to lie in distinct but incomplete bony cavities of their own. The bone surrounding the tooth-sacs, temporary and permanent, is always wanting over the summit of the sac, and the band of connective tissue by which the sac is connected with the overlying gum tissue, through the deficiency, is known as the **gubernaculum dentis.**

These points are easily demonstrated on the lower jaw of a child at birth, particularly when the tissues have been allowed to soften a little. If, in such a specimen, the gum and periosteum be reflected upwards from the outer and inner surfaces of the mandible, and freed as far as the upper border of the jaw, the gum, with the tooth-sacs depending from it like small bags, can be pulled away out of the bony groove of the jaw; and if the operation has been successfully performed, the tooth-sacs of the three front permanent teeth may be seen, varying in size from a small pin's-head to a hemp-seed, hanging down behind the upper part of the corresponding temporary sacs. As already explained, the tooth-sacs are produced simply by a condensation of the connective tissue around the developing tooth, the condensation going on to the formation of a distinct membranous bag.

Formation of Alveoli and Eruption.—At first the developing teeth lie in an open bony groove or channel between the outer and inner plates of the young jaw. This groove is subsequently divided up into separate compartments for the sacs of each of the temporary teeth. As development proceeds these compartments or alveoli surround the sacs more completely, but never actually close over the summit. When the eruption of the temporary teeth is about to take place, the anterior wall and roof of the alveolus are absorbed; the tooth passes through the sac and appears above the gum, and then the alveolus, which up to this was much too large to give actual support, is re-formed more closely around the tooth. Meanwhile the root, which was only partly formed at the time of the eruption, continues to be added to, possibly for a few years more, and, as it grows, the alveolus is completed around it. When the permanent tooth, or as much of it as is then formed, is about to be erupted, it makes its way from its own bony cell through the posterior wall of the alveolus of its temporary predecessor; the root of the temporary tooth undergoes absorption at the same time, but quite independently of pressure from the permanent tooth. The alveolus, now occupied by both teeth, is again much enlarged by absorption, particularly in front; what remains of the temporary tooth is shed; the permanent tooth passes onwards through the enlarged alveolus, and, making its way to the surface, appears above the gum. After some time, when the tooth has taken its final position, the alveolus is again re-formed, first around its neck, and later on, as the root is built up, around it also, and thus the tooth is permanently fixed.

What the force is which causes the eruption, is a question that has not been answered satisfactorily. That the growth of the root pushes up the crown was until recently the

favourite explanation. For several reasons, unnecessary to detail, this view is now discarded, and a theory which attributes the impelling force to the blood pressure is looked upon with more favour, although even this is not altogether satisfactory. (See Tomes' *Dental Anatomy*, 5th Edition, page 211.)

Morphology of the Teeth.

In most vertebrates below mammals all the teeth are alike in form; such a dentition is said to be **homodont.** In the majority of mammals, on the other hand, the teeth are arranged in groups of different size and form; such a dentition is **heterodont.**

Again, mammals have, neglecting exceptional cases, but two functional sets of teeth; they are consequently said to be **diphyodont.** Most vertebrates below mammals, on the other hand, have a continuous succession of teeth throughout life, and hence are said to be **polyphyodont.**

Seeing that practically all lower vertebrates are provided with simple conical teeth, the evolution of the many-cusped mammalian molar has given rise to much speculation. The jaws of the earliest fossil mammals found are furnished with tri-tubercular teeth, the three tubercles being placed in an antero-posterior line; by a rotation of two of the cusps out or in, as the case may be (a condition found in certain other fossil skulls), we arrive at a tri-tubercular form, from which the transition to an ordinary mammalian molar is not difficult. As to how the tri-tubercular tooth arose from the simple cone, two different views are advanced: one, that it was formed by the union of several conical teeth as a result of the shortening of the jaw and the crowding of the teeth together; the other, that the single conical tooth developed lateral buds or outgrowths, and that these buds growing larger, the tooth assumed the tri-tubercular form.

The complete or **typical mammalian dentition**, in its highest development, as in the horse, is represented by the following formula: i, $\frac{3}{3}$, c. $\frac{1}{1}$, pm. $\frac{4}{4}$, m. $\frac{3}{3}=44$. In the dentition of man, therefore, one incisor and two premolars are wanting. Different views are held as to which teeth have been suppressed—most probably they are the second incisors, and the first and second or first and last premolars.

In general it may be said that the **dentition of the lower races** differs from that of the higher, in that the dental arches are squarer in front, the teeth larger and more regular, the canines stronger, the wisdom teeth better developed, and the cusps on the molars more perfect, in the lower than in the more civilised races. However, according to Tomes, the teeth of a savage man, if seen in the mouth of a European, would be looked upon as an "exceedingly perfectly-formed set of teeth."

To express the proportionate size of the crowns of the premolars and molars to that of the skull in different races, Flowers compared the distance from the front of the first premolar to the back of the last molar, *in situ*, with the distance from the front of the foramen magnum to the naso-frontal suture (basi-nasal length), in the form of a "dental index"—

$$\text{Thus: } \frac{\text{Length of teeth} \times 100}{\text{Basi-nasal length}} = \text{Dental index},$$

and by this means he divided the various races into **microdont** (index 42 to 43, Europeans, Egyptians, etc.), **mesodont** (index 43 to 44, Chinese, American Indians, Negroes, etc.), and **macrodont** (index 44 and upwards, Australians, Melanesians, etc.).

THE PHARYNX.

The **pharynx** is the expanded upper portion of the digestive tube which lies behind, and communicates with, the mouth, the larynx, and the nasal cavities (Fig. 660). It serves for the passage of both air and food, conveying the former to the larynx and the latter to the œsophagus.

It extends from the base of the skull above to the level of the sixth cervical vertebra below (Fig. 661), where, opposite the lower border of the cricoid cartilage, it passes into the œsophagus; its total length varies from 5 to $5\frac{1}{2}$ inches (12·5 to 14·0 cm.).

When in its natural state within the body, the pharynx is expanded laterally and compressed in the opposite direction, so that its anterior and posterior walls approach one another, and its sides are reduced to little more than mere borders. Although its cavity is much reduced by this approximation of the anterior and posterior walls, there is always left, above the orifice of the larynx, a sufficient space for the entrance of air to the lungs. Below the laryngeal orifice, on the other hand, the anterior and posterior walls are in contact, and the cavity, except during the passage of food, is reduced to a transverse slit (Fig. 661).

As usually seen in the dissecting-room, when distended for dissection, the pharynx is of an elongated oval form, tapering rapidly below. This form, however, is due entirely to the artificial conditions under which it is placed.

Taken as a whole, the pharynx is a tube, the anterior wall of which is wanting. The place of this wall is occupied by the nasal, oral, and laryngeal cavities, as well as by the base of the tongue; and to the lateral boundaries of all of these parts the sides of the tube are connected. In this way it comes to be attached from above downwards to the following more or less fixed points:—(1) The Eustachian tube and internal pterygoid plate; (2) the pterygomaxillary ligament, the posterior end of the mylohyoid ridge on the inner aspect of the lower jaw, and the mucous membrane of the mouth; (3) the base of the tongue and the hyoid bone; and (4) the thyroid and cricoid cartilages of the larynx. Above, it is firmly fixed by its aponeurosis to the periosteum of the basi-occipital and petrous portion of the temporal bones; and in addition the raphe of the constrictors is attached to the pharyngeal tubercle of the occipital bone. Below it becomes continuous with the œsophagus. Behind and at the sides, the pharynx is connected merely by loose areolar tissue to the surrounding parts.

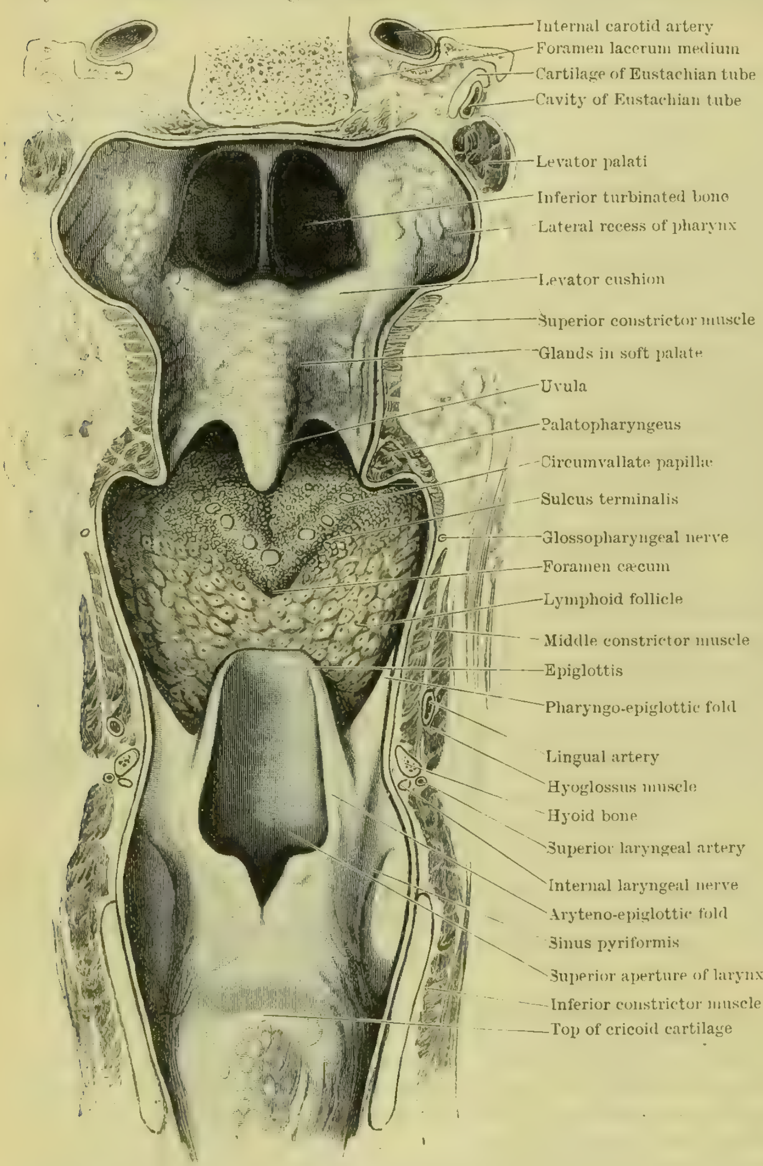


FIG. 660.—THE ANTERIOR WALL OF THE PHARYNX WITH ITS ORIFICES, SEEN FROM BEHIND.

The specimen from which the drawing was made was obtained from a formalin-hardened body, by removing the posterior wall of the pharynx while leaving the anterior wall undisturbed. The following points should be noted: the greatest width of the pharynx, above, at the lateral recesses; the posterior nares, with the inferior turbinated bones seen through them; the levator cushion; and the pharyngeal portion of the tongue.

The pharynx presents the following **relations**:—*In front,* as already described, are the nasal cavities, the mouth, base of tongue, and larynx, all of which are seen on its anterior wall (Fig. 660). *Behind,* it is separated by loose areolar tissue (known as the **retro-pharyngeal space**) from the prevertebral fascia and muscles, which intervene between it and the six upper cervical vertebræ. *At the sides* are placed the

carotid sheaths with their contents, whilst the styloid process with its muscles, and the glosso-pharyngeal nerve, running downwards and forwards, form lateral relations in its upper part. *Above*, the pharynx is united to the basi-occipital and the petrous portion of the temporal bones, as already described; and *below*, it joins the œsophagus.

The **cavity of the pharynx** is widest above in the naso-pharynx, immediately behind the Eustachian tubes (Fig. 660), where it extends out on each side, over the upper border of the superior constrictor, in the form of a pouch—the **lateral**

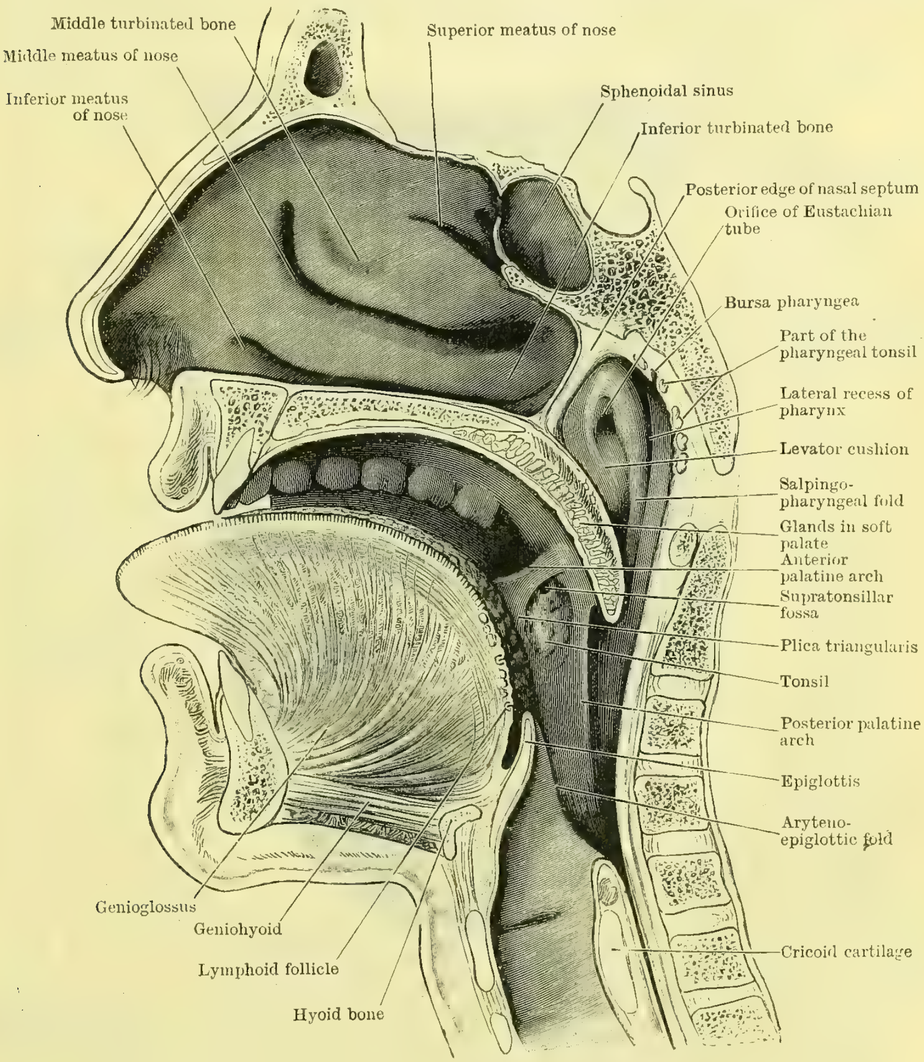


FIG. 661.—SAGITTAL SECTION THROUGH MOUTH, TONGUE, LARYNX, PHARYNX, AND NASAL CAVITY.

The section is slightly oblique, and the posterior edge of the nasal septum has been preserved. The specimen is viewed slightly from below, hence in part the low position of the inferior turbinated bone.

recess. Its width is also considerable opposite the upper part of the thyroid cartilage, but it rapidly diminishes below the laryngeal orifice, and is narrowest at its termination in the œsophagus.

The cavity is interrupted above by the soft palate, a movable muscular sheet, which is attached in front to the hard palate, and laterally to the side walls of the pharynx. This sheet, sloping obliquely backwards and downwards, cuts into the cavity of the pharynx (Fig. 661), and, falling short of the posterior wall, incompletely divides it into two, namely, an upper part or **naso-pharynx** (pars nasalis), and a

lower part or pharynx proper, which is further subdivided—perhaps unnecessarily—into the **oral pharynx** (pars oralis) lying behind the mouth and tongue, and the **laryngeal pharynx** (pars laryngea) behind the larynx.

The aperture left between the soft palate and the posterior wall of the pharynx, through which the naso-pharynx communicates with the lower divisions of the cavity, may conveniently be called the **pharyngeal isthmus** (isthmus pharyngo-nasalis).

The pharynx presents *seven openings* through which it communicates with neighbouring cavities (Fig. 660). These are the two posterior nares (choanæ) on the anterior wall, and the two Eustachian tubes on the sides of the naso-

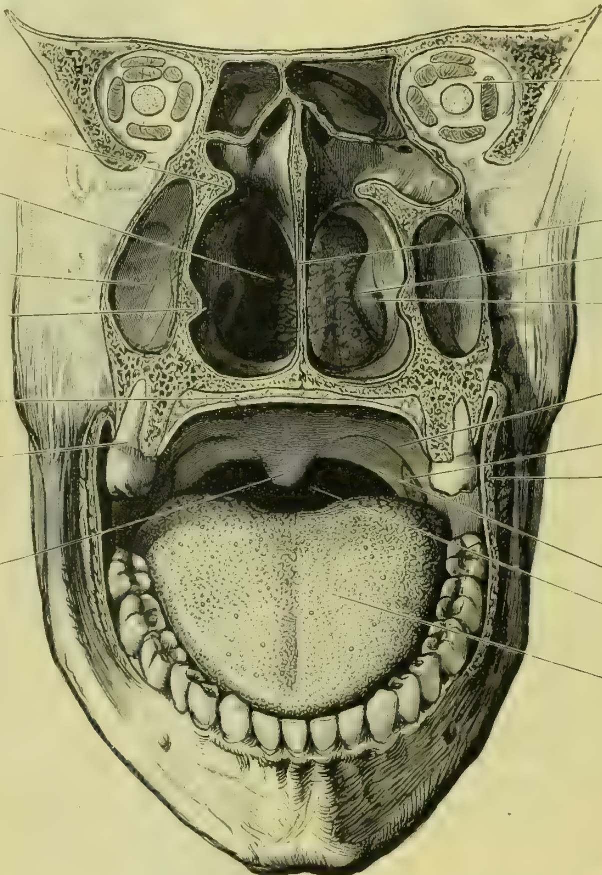


FIG. 662.—THE NASO-PHARYNX FROM THE FRONT.

A coronal section was made through the upper part of the head; this passed immediately in front of the posterior edge of the nasal septum, and extended into the mouth below. Through the posterior nares the naso-pharynx is seen. The prominence of the posterior margin of the Eustachian orifice, and the lymphoid nodules constituting the pharyngeal tonsil, should be noted. The palatine arches, the tonsils, and an unusually wide pharyngeal isthmus, are also seen.

pharynx; the isthmus of the fauces leading into the mouth from the oral pharynx; the orifice of the larynx on the anterior wall of the laryngeal portion of the cavity; and finally, the opening of the œsophagus at its lower end.

Naso-pharynx (Figs. 661 and 662).—Although described as a part of the pharynx, this portion of the cavity should be regarded as an annex to the respiratory portion of the nasal cavities rather than as a subdivision of the pharynx proper, for, both anatomically and functionally, it is all but completely marked off from the digestive tube. It differs from the rest of the pharynx in that its cavity remains, under all conditions, a distinct open chamber incapable of obliteration, owing to the fact that all its walls, with the single exception of the floor, are practically immovable.

The chamber of the naso-pharynx is irregular in shape, and is enclosed by *six walls*—namely, anterior, posterior, two lateral, and a floor—together with a roof or vault formed above by the approximation of the anterior and posterior walls.

The *anterior wall*, which slopes upwards and backwards, is entirely occupied by the two posterior nares, with the nasal septum between them (Fig. 660).

The *posterior wall* is inclined upwards and forwards, and forms the **vault of the pharynx** (fornix pharyngis) above by meeting the anterior wall at a rounded angle. On the upper part of the posterior wall, at and above the level of the Eustachian orifices, there is seen, particularly in early life, a considerable accumulation of lymphoid tissue, associated with a thickened and folded condition of the mucous membrane in the child. This is the **pharyngeal tonsil** (tonsilla pharyngea, Figs. 661 and 662). In old age it becomes very indistinct, or completely disappears; whilst in the child it is often increased in size, and occasionally, when greatly hypertrophied, blocks up the naso-pharynx almost completely.

In connexion with the lower part of the pharyngeal tonsil, there is found, constantly in the child and occasionally in the adult, a small median recess which runs upwards and backwards in the wall of the pharynx for some distance, and is known as the **bursa pharyngea** (Fig. 661).

Three leading views are held as to the nature of the bursa pharyngea, namely—1. That it is the remains of Rathke's pouch, from which the anterior lobe of the pituitary body is formed. 2. That it is a crypt connected with the formation of the pharyngeal tonsil. 3. That it is an independent outgrowth of the mucous membrane. The last view is perhaps most generally accepted.

The *floor* of the naso-pharynx is formed by the upper surface of the soft palate (Fig. 661), which in its anterior part is a direct continuation backwards of the floor of the nasal cavity, whilst posteriorly it slopes strongly downwards and backwards. Between the floor and the posterior wall is left the aperture referred to above as the pharyngeal isthmus, through which the naso-pharynx communicates with the rest of the pharyngeal cavity. By the action of the palatal muscles the floor can be raised or depressed, and these changes of position are accompanied by corresponding alterations in the size and shape of the cavity.

Each *lateral wall* of the naso-pharynx (Fig. 661) is occupied in the greater part of its extent by the opening of the Eustachian tube, behind which is seen a vertical slit-like depression leading into a recess, the **lateral recess** of the pharynx, or **fossa of Rosenmüller**.

The **pharyngeal orifice of the Eustachian tube** (ostium pharyngeum) is a considerable opening, usually of a somewhat triangular form, with a characteristic infundibular or funnel-like appearance (Fig. 661). It is bounded above and behind by a prominent rounded ridge, the **Eustachian cushion** (torus tuberius). This ridge is due to the projection of the cartilage, which surrounds the Eustachian passage above and behind, but is absent below and in front. The prominence of the posterior, as contrasted with the anterior margin of the orifice, and the direction of the tube itself, which runs strongly forwards as well as inwards (traced from the tympanum), greatly facilitate the introduction of a Eustachian catheter.

The exact position of the orifice is of importance in connection with this latter operation. It is situated on the side-wall of the naso-pharynx, a short distance (about $\frac{1}{3}$ to $\frac{1}{2}$ inch) behind the posterior end of the inferior turbinated bone, and immediately above the level of the hard palate (Figs. 661 and 662).

A slight ridge of the mucous membrane descends from the lower end of the Eustachian cushion on the side-wall of the pharynx, and gradually becomes lost. This is known as the **salpingo-pharyngeal fold** (plica salpingo-pharyngea). Another less developed ridge, the **salpingo-palatine fold** (plica salpingo-palatina), passes from the anterior border of the Eustachian orifice downwards and forwards to join the palate. In front of the latter lies an indistinct groove, the **naso-pharyngeal groove**, which indicates the separation of the nasal cavity from the naso-pharynx.

The levator palati muscle in descending runs parallel to the Eustachian tube, and along its lower border. As it enters the palate, it produces, particularly when in a state of

contraction, an elevation just below the Eustachian orifice, known as the **levator cushion** (torus levatorius, Figs. 660 and 661), which in its outer portion abuts against the lower part of the orifice, and forms its base when that opening assumes its usual triangular shape.

Occasionally the Eustachian orifice is of an oval or slit-like form, with sloping edges, but the triangular shape described above is much more commonly found.

Immediately behind each Eustachian orifice is seen the **lateral recess of the pharynx** (recessus pharyngeus, fossa of Rosenmüller), a nearly vertical, slit-like depression of considerable depth (Figs. 660 and 661), which runs outwards in the form of a flattened pouch or diverticulum.

The lateral recesses project out over the upper margin of the superior constrictor, and beneath the petrous portion of the temporal bone, corresponding to the position of the sinus of Morgagni on each side. The recess is the remains of the inner or pharyngeal portion of the second visceral cleft, the lower part of which is represented in the supratonsillar fossa.

Oral Pharynx (pars oralis).—This is the portion of the pharyngeal cavity which lies behind the mouth, and intervenes between the soft palate above and the superior aperture of the larynx below. Its *anterior wall* is occupied by the isthmus of the fauces, leading into the mouth; and below this by the pharyngeal portion of the tongue, almost vertical in direction. Its *lateral wall* (Fig. 661) presents a triangular area (sinus tonsillaris), bounded in front by the anterior palatine arch, behind by the posterior palatine arch, and below by the sides of the tongue in its pharyngeal portion. This area is occupied in the greater part of its extent by the **tonsil**, above which is found a depression, the **supratonsillar fossa** (Fig. 661), which is of considerable interest clinically.

The **posterior palatine arch** (arcus pharyngo-palatinus, posterior pillar of the fauces) is a prominent fold of mucous membrane, containing the palato-pharyngeus muscle in its interior, which springs above from the posterior edge of the soft palate, and, passing downwards and slightly backwards, ends below on the side-wall of the pharynx (Fig. 661). The two posterior palatine arches form the lateral boundaries of the pharyngeal isthmus, which passage they can modify both in size and shape by the contraction of their contained muscles.

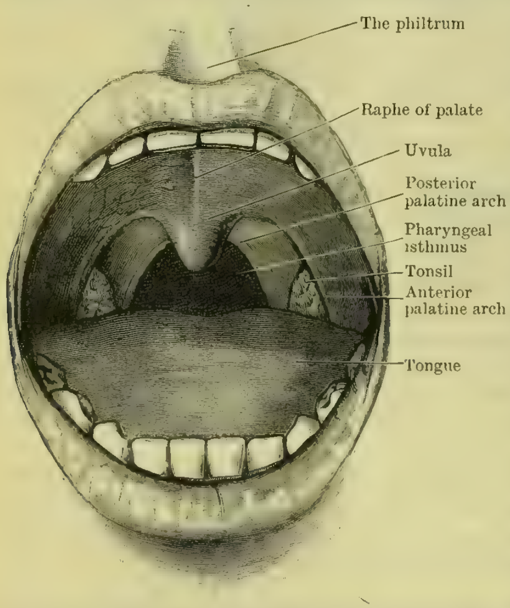


FIG. 663.—OPEN MOUTH SHOWING PALATE AND TONSILS.

It also shows the two palatine arches, and the pharyngeal isthmus through which the naso-pharynx above communicates with the oral portion of the pharynx below.

The anterior palatine arch is described on page 950.

The **pharyngeal isthmus** (isthmus pharyngo-nasalis) is the very oblique and somewhat triangular orifice through which the oral pharynx communicates with the naso-pharynx (Fig. 663). It differs considerably in size and shape in different individuals, being in some so small that the naso-pharynx can be explored from the mouth only with very great difficulty; whilst in others it is of much larger dimensions (Fig. 662) and affords ample space for the rhinoscopic examination of the naso-pharynx and the back part of the nasal cavities.

In general it may be described as triangular in shape, the sides corresponding to the posterior palatine arches, and the base, which is behind, being formed by the posterior wall of the pharynx. The apex of the triangle is directed towards the soft palate, and is encroached upon, and overlapped from below by, the uvula, which assists in the closure of the orifice (Fig. 663).

By the contraction of the palato-pharyngei muscles, which are enclosed within the palatine arches, the sides of the isthmus can be approximated, like two curtains, and its size correspondingly diminished. When, at the same time, the uvula and soft palate are elevated, and the whole pharynx in this region is narrowed by the contraction of the superior constrictor, the aperture can be completely closed, and the oral separated from the nasal pharynx, as in the acts of swallowing and vomiting.

The **tonsils** (tonsillæ palatinæ, amygdalæ) are two large, oval masses of lymphoid tissue which are embedded in the lateral walls of the oral pharynx, between the anterior and posterior palatine arches (Fig. 661). As already pointed out, there is in this region a triangular interval (the sinus tonsillaris), situated between the two

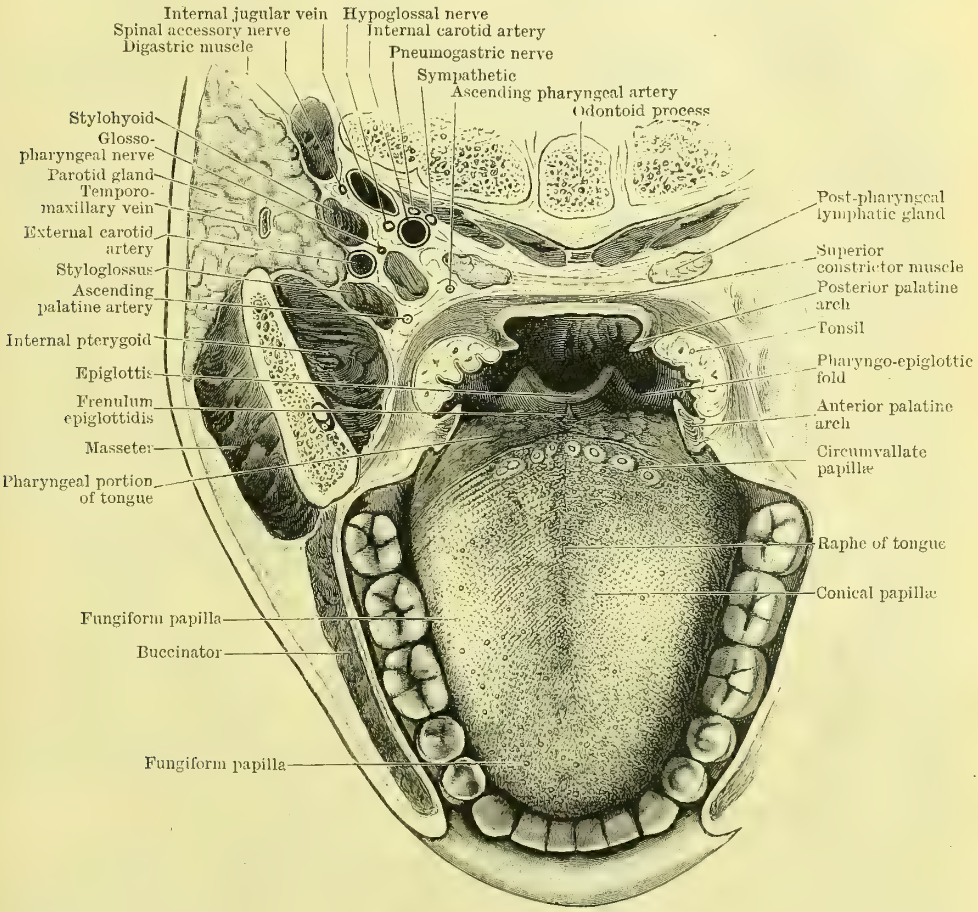


FIG. 664.—HORIZONTAL SECTION THROUGH MOUTH AND PHARYNX AT THE LEVEL OF THE TONSILS.

The stylopharyngeus, which is shown immediately to the inner side of the external carotid artery, and the prevertebral muscles, are not indicated by reference lines.

palatine arches and the side of the tongue. The greater part of this interval is occupied by the tonsil. In its upper part, however, above the tonsil, there is usually found a variably-developed depression already referred to as the **supra-tonsillar fossa.**

The tonsil lies under cover of the ramus of the jaw, and corresponds in position to a point a little above and in front of its angle. Its *inner* or *pharyngeal surface* is prominent, and closely beset with numerous deep, pit-like depressions—the crypts of the tonsil. These crypts are most numerous in the upper part of the mass, where, in particular, they form a series of irregular inter-communicating passages.

The *outer* or *attached surface* is enclosed in a distinct fibrous capsule connected with the pharyngeal aponeurosis, outside which lie the superior constrictor of the pharynx and the internal pterygoid muscles (Fig. 664).

The ascending palatine artery, running upwards and backwards between the stylo-glossus and stylo-pharyngeus, lies in close relation to the outer surface of the tonsil—separated only by its capsule and the superior constrictor—as does also the tonsillar artery, which is often represented by a branch of the last. More external still lies the internal pterygoid and the ramus of the jaw; whilst the internal carotid artery, with the large cranial nerve trunks, is placed $\frac{3}{4}$ to 1 inch behind and to its outer side (Fig. 664).

The size of the tonsils is extremely variable, but as a rule, in early life, they measure something under 1 inch (20 to 22 mm.) from above downwards, about $\frac{3}{4}$ inch (18 to 20 mm.) antero-posteriorly, and $\frac{1}{2}$ inch (12 to 15 mm.) from within out.

In the child and young adult there is usually seen a thin triangular fold of mucous membrane, **the plica triangularis** (His), which stretches from the anterior palatine arch backwards for a variable distance over the tonsil (Fig. 661). Its apex is directed upwards towards the soft palate, its base towards the tongue, and its free margin crosses the tonsil, to which it often adheres in later life. In this latter condition the plica encloses a more or less distinct space situated between itself and the tonsil, in which diseased processes are often set up.

Above the tonsil, as already mentioned, is found a variably-developed depression, the **supratonsillar fossa**, which occasionally is of considerable size, and then extends either upwards into the soft palate or forwards and downwards beneath the plica triangularis. This fossa is frequently the seat of suppurative changes, and is consequently of considerable clinical importance.

The supratonsillar fossa, like the lateral recess of the pharynx, is the remains of the pharyngeal portion of the second visceral cleft. The palate in its growth backwards crosses the cleft, which it divides into two parts—namely, the pharyngeal recess above, and the supratonsillar recess below the soft palate.

In the severe hæmorrhage which has been known to follow excision of an enlarged tonsil, and which has been erroneously attributed to the wounding of the internal carotid artery, the blood is derived chiefly from enlarged branches of the ascending palatine, tonsillar, or ascending pharyngeal vessels.

The **arteries** of the tonsil are derived from the ascending palatine and tonsillar branches of the facial, the ascending pharyngeal of the external carotid, and the dorsalis linguæ of the lingual. The **veins** pass to the tonsillar plexus, on the outer side of the tonsil, which is an offshoot of the pharyngeal venous plexus.

Nerves.—The tonsil receives a special branch from the glosso-pharyngeal; this unites with branches from the pharyngeal plexus in a small **plexus tonsillaris** which supplies the organ.

The **lymphatics** are extremely numerous, and pass down to join some of the submaxillary lymphatic glands near the angle of the jaw.

Laryngeal Portion of the Pharynx (pars laryngea).—This division of the pharyngeal cavity lies behind the larynx (Fig. 660). It is wide above, where it is continuous with the oral portion, and maintains a considerable width until within about an inch of its termination, when behind the cricoid cartilage it narrows rapidly and passes down to join the œsophagus. Except during the passage of food, the anterior and posterior walls of this latter part are in contact, and its cavity is reduced to a mere transverse slit (Fig. 661).

The *anterior wall* of the laryngeal portion of the pharynx is formed in its whole extent by the back of the larynx, of which the following parts are seen within the pharyngeal cavity (Fig. 660):—The epiglottis above; below this the superior aperture of the larynx, bounded at the sides by the aryteno-epiglottic folds; outside these folds is seen on each side a deep recess, the **sinus pyriformis** (recessus piriformis, Fig. 660). Lower down still, the back of the arytenoid and cricoid cartilage, covered by muscles and mucous membrane, are visible.

Its posterior and *lateral walls* are directly continuous with the corresponding walls of the oral pharynx, and present no features which require special notice.

A prominent fold of the mucous membrane, extending from the side of the epiglottis, runs up along the lateral wall, upon which it ends near the posterior palatine arch. This, the **pharyngo-epiglottic fold**, is often described as a lateral glosso-epiglottic fold.

The **sinus pyriformis** is a deep depression, seen on each side between the aryteno-epiglottic fold and the ala of the thyroid cartilage. When viewed from above, as in laryngoscopic examinations, it appears of a pyriform shape, the wider end being directed upwards and forwards. When viewed from behind, the recess is boat-shaped and elongated in the vertical direction. Its outer wall is formed by the thyroid cartilage and thyro-hyoid membrane, covered by mucous membrane; its

inner wall by the aryteno-epiglottic fold, and slightly below by the upper part of the cricoid cartilage.

Vessels and Nerves of the Pharynx.—The **arteries** of the pharynx are derived from—1, the ascending pharyngeal; 2, the ascending palatine branch of facial; 3, the posterior palatine, from the internal maxillary, with a few twigs from the dorsalis linguæ, tonsillar (of facial), vidian, and pterygo-palatine of the internal maxillary. The **veins** go to the pharyngeal venous plexus, which is found between the constrictors and the bucco-pharyngeal aponeurosis. The plexus communicates with the pterygoid plexus above and with the internal jugular or facial vein below.

The **lymphatics** of the pharynx pass chiefly to the upper set of deep cervical glands. Those from the upper part of the posterior wall join a few post-pharyngeal glands which are found on each side between the pharynx and the rectus anticus major muscle. These latter glands, which are large in the child, small in the adult, but apparently always present (Fig. 664), are of considerable clinical interest, as they often form the starting-point of post-pharyngeal abscess.

The **nerves** of the pharynx, both motor and sensory, are derived chiefly from the pharyngeal plexus, which is formed by branches of the vagus, glosso-pharyngeal, and sympathetic. The soft palate and the neighbourhood of the tonsil are supplied by the posterior and external palatine branches of Meckel's ganglion. The tonsil receives a branch from the glosso-pharyngeal direct. The vault of the pharynx, and the region around the Eustachian orifice, as well as the orifice itself, are supplied by the pharyngeal branch of Meckel's ganglion. Finally, the superior laryngeal nerve supplies the mucous membrane of the back of the larynx, where it forms the anterior wall of the laryngeal portion of the pharynx.

Structure of the Pharyngeal Wall.—The pharyngeal wall is made up of the following layers:—(1) The thick mucous membrane, which is plentifully supplied with racemose mucous glands, and lymphoid tissue, and is lined by stratified squamous epithelium, except in the naso-pharynx, where the epithelium is columnar and ciliated. (2) Outside the mucous membrane lies a layer of firm connective tissue, the pharyngeal aponeurosis, which is closely associated with the muscles, and receives the insertions of many of their fibres. This layer blends with the periosteum of the base of the skull superiorly, and is united to the Eustachian tube, the margins of the posterior nares, and the other fixed points to which the pharynx is connected anteriorly. It is thickest above, at the sinuses of Morgagni, where the muscular coat is wanting, and where it forms the chief constituent of the pharyngeal wall. Below, it gradually grows thinner as the lower end of the pharynx is approached. (3) External to the pharyngeal aponeurosis lies the muscular coat, formed of the three constrictors with the stylo- and palato-pharyngeus. The muscular coat is covered externally by (4) the bucco-pharyngeal fascia, a thin and, in places, ill-defined layer of fascia which surrounds the constrictors of the pharynx, and passes forward above to cover the outer surface of the buccinator. It is connected behind to the prevertebral fascia by loose connective tissue (the retro-pharyngeal space), and it is similarly connected by areolar tissue to the other structures with which the pharynx comes in contact.

The racemose glands of the mucous membrane, which are of the mucous type, are very numerous in the walls of the naso-pharynx and in the soft palate, where they form a thick continuous layer. They are also numerous about the aryteno-epiglottic folds and on the back of the arytenoid muscles in the laryngeal portion of the pharynx. Over the rest of this cavity, though numerous, they are not so thickly placed as in the regions just mentioned. The lymphoid tissue, either in a diffuse form or collected into lymphoid follicles, is found throughout the whole of the mucous membrane. As already pointed out, it is particularly abundant on the upper portion of the posterior wall of the naso-pharynx, where it forms the pharyngeal tonsil.

The pharyngeal aponeurosis, which is thick above and thin below, and the bucco-pharyngeal fascia, which is thin above and stouter below, are practically blended into one layer above, near the base of the skull, where the muscular coat is absent. Lower down they are separated by the constrictors, and become two distinct sheets. They are strengthened in the middle line posteriorly by a fibrous band descending from the pharyngeal tubercle.

Development of the Pharynx and Tonsil.

For the development of the pharynx from the anterior portion of the foregut, and the formation and fate of the visceral arches and clefts which are found in its wall, the reader is referred to the chapter on General Embryology, p. 32.

The anterior palatine arch is derived from the second visceral arch, behind which, in the embryo, lies the pharyngeal portion of the second visceral cleft. This cleft is crossed

by the palate in its growth backwards; the part above the palate is represented in the adult by the lateral recess of the pharynx and the part below it by the sinus tonsillaris. From the lower and greater part of the sinus tonsillaris the tonsil is developed; the upper part of the sinus persists, however, as the supratonsillar fossa. The tonsil at first is a smooth depression of the mucous membrane. About the fourth month of fœtal life downgrowths of the epithelium take place, which are afterwards converted into the tonsillar crypts. Subsequently lymphoid cells accumulate around the downgrowths and form the lymphoid tissue, which constitutes the mass of the organ.

The upper and anterior part of the naso-pharynx is derived from the stomatodeum, the remainder of the cavity from the foregut.

THE ŒSOPHAGUS.

The **œsophagus** or **gullet** is the portion of the digestive canal which intervenes between the pharynx above and the stomach below. With the exception of the pylorus, it is the narrowest, and at the same time one of the most muscular parts of the whole alimentary tube.

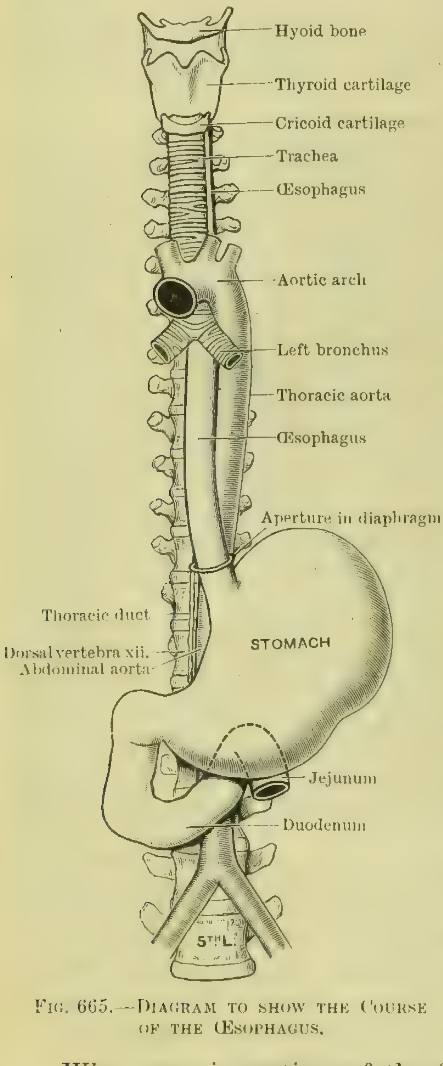


FIG. 665.—DIAGRAM TO SHOW THE COURSE OF THE ŒSOPHAGUS.

It extends from the termination of the pharynx, at the lower border of the cricoid cartilage and opposite the sixth cervical vertebra, to the cardiac orifice of the stomach, opposite the eleventh dorsal vertebra. Between these two points it traverses the lower part of the neck, the whole length of the thorax, and, having pierced the diaphragm, it enters the abdomen, and immediately afterwards joins the stomach. In this course it does not adhere to the mesial plane of the body, but twice leaves it, and curves to the left. The first of these curvatures corresponds to the lower part of the neck and the upper part of the thorax, where the œsophagus projects beyond the left margin of the trachea to the extent of $\frac{1}{6}$ or $\frac{1}{4}$ inch (4 to 6 mm.). It returns to the middle line about the level of the aortic arch. Lower down, behind the pericardium, it again passes to the left, and at the same time forwards, in order to reach the œsophageal opening in the diaphragm (which is placed in front and to the left of the aortic opening), and it maintains this direction until the stomach is reached.

In addition to the curvatures just described, it is also curved in the antero-posterior direction, in correspondence with the form of the vertebral column upon which it, in great part, lies.

In *length* it usually measures about ten inches (25 cm.).

Its *breadth*, where the tube is widest, varies between half an inch (13 mm.) in the empty contracted condition and an inch or more (25 to 30 mm.) in the fully distended state.

When seen in sections of the frozen body (Fig. 666), the œsophagus usually appears either as a flattened tube with a transverse slit-like cavity, or as an oval or rounded canal with a more or less stellate lumen. The former condition is more common in the neck, owing to the pressure of the trachea, and the latter in the thorax.

When exposed in the ordinary post-mortem examination soon after death,

it has rather the appearance of a solid muscular rod or band than of a hollow tube.

The œsophagus presents two distinct *constrictions,* one situated at its beginning, the other at the point where it is crossed by the left bronchus. Both constrictions are of the same size, and will admit without injury an instrument with a maximum diameter of $\frac{4}{5}$ inch (20 mm.). At each of these points the tube is flattened from before backwards.

The œsophagus varies in length in different individuals, from 8 to 14 inches (20 to 35 mm.). The distance from the upper incisors to the beginning of the œsophagus averages about 6 inches (15 cm.).

During life the cervical portion is said, under ordinary circumstances, to be closed and flattened from before backwards by outside pressure, whilst the thoracic portion may be open owing to the negative pressure in the thorax. The passage into the stomach is also said to be open (Mickulicz), but this is doubtful.

The size at the two constrictions, when the tube is fully distended, is 23 mm. transversely, and 17 mm. antero-posteriorly. The other parts vary in diameter between 26 and 30 mm. (Jonnesco).

In its first curvature to the left the divergence is greatest opposite the third dorsal vertebra. The second inclination to this side begins about the seventh dorsal vertebra, and continues to the end of the œsophagus, being considerably increased as the diaphragm is approached.

Relations of the Œsophagus. — The relations (Fig. 666) differ so widely in the neck and thorax that they must be described separately for each of these regions.

In the neck.—*In front* lies the trachea—to the posterior membranous wall of which the œsophagus is loosely connected by areolar tissue—and in the groove at each side, between the two, the recurrent laryngeal nerve ascends to the larynx (Fig. 666, A). *Behind* lie the vertebral column and the longus colli muscles, from which the œsophagus is separated by the prevertebral layer of the cervical fascia. *At the sides* are placed the carotid sheaths with their contained vessels, and the lateral lobes of the thyroid body. Owing to the deviation of the tube to the left in the lower part of the neck, its relation to the carotid sheath and thyroid body is much more intimate on this than on the right side.

In the thorax.—The œsophagus passes successively through the superior and posterior mediastina, in the former lying close to the vertebral column, but in the latter advancing somewhat into the thoracic cavity and coming into contact with the back of the pericardium. The trachea still lies *in front* as far as its bifurcation. Immediately

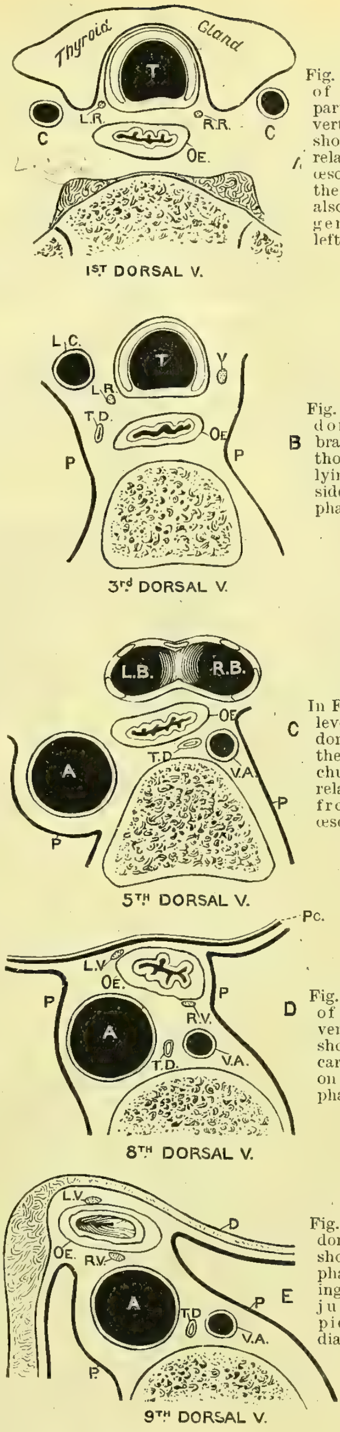


Fig. A is at level of the upper part 1st dorsal vertebra, and shows the chief relations of the œsophagus in the neck and also its divergence to the left.

Fig. B, at the 3rd dorsal vertebra, shows the thoracic duct lying on left side of the œsophagus.

In Fig. C, at the level of the 5th dorsal vertebra, the left bronchus is seen in relation to the front of the œsophagus.

Fig. D is at level of 8th dorsal vertebra, and shows the pericardium lying on front of œsophagus.

Fig. E, at 9th dorsal vertebra, shows the œsophagus inclining to the left just before piercing the diaphragm.

Fig. 666.—Tracings from Frozen Sections to show the Relations of the Œsophagus at the levels of the 1st, 3rd, 5th, 8th, and 9th dorsal vertebræ respectively.

A, Aorta; C, Common carotid artery; D, Diaphragm; L.B, Left bronchus; L.C, Left subclavian artery; L.R, Left recurrent nerve; L.V, Left vagus; Oe, Œsophagus; P, Pleura; Pc, Pericardium; R.B, Right bronchus; R.R, Right recurrent nerve; R.V, Right vagus; T, Trachea; T.D, Thoracic duct; V.A, Vena azygos major.

below this the œsophagus is crossed by the left bronchus (Fig. 666, C), and in the rest of its thoracic course it lies in the closest relation to the back of the pericardium. *Behind*, it rests on the longus colli muscle and the vertebral column in the upper part of the thorax; but below the bifurcation of the trachea, as already explained, it advances into the cavity of the posterior mediastinum, and is soon separated from the spine by the vena azygos major, the thoracic duct, and in its lower part by the aorta as well.

On its *left side* lie the thoracic duct, the pleura, and the left subclavian artery in the upper part of the thorax; the aorta in the middle region; and lower down the pleura again, for a little way, before the œsophagus pierces the diaphragm. On the *right side* the tube comes into relation with the arch of the azygos vein, whilst below this the pleura clothes it.

The two pneumogastric nerves, after forming the posterior pulmonary plexuses behind the roots of the lungs, descend to the œsophagus, where they form, by uniting with one another and with the branches of the sympathetic, the **plexus gulæ** or **œsophageal plexus**. Lower down the left nerve winds round to the front, whilst the right turns to the back, and in this relation they pass with the tube through the diaphragm to reach the stomach.

Relation of the Aorta to the Œsophagus.—The arch of the aorta, passing back to reach the vertebral column, lies in relation to the left side of the œsophagus; consequently the descending thoracic aorta lies at first to its left; lower down, however, as the aorta passes on to the front of the vertebral column, and the gullet inclines forwards and to the left, the œsophagus comes to lie at first in front, and then, as the diaphragm is approached, it lies not only in front, but also somewhat to the left of the artery (Figs. 665 and 666).

Relation of the Thoracic Duct to the Œsophagus.—The thoracic duct, lying to the right of the aorta below, is not directly related to the œsophagus (Fig. 666, E); but higher up (Fig. 666, D and E) it lies behind it. About the level of the aortic arch the duct passes to the left, and above this (Fig. 666, B and A) will be found resting against the left side of the œsophagus, which it accompanies into the neck.

Relation of the Pleural Sacs to the Œsophagus.—Above the level of the aortic arch and the arch of the vena azygos major, between which the tube descends, the pleuræ, though not lying in immediate contact with the œsophagus, are separated from it only by a little connective tissue, and on the left side also, behind the subclavian artery, by the thoracic duct (Fig. 666, B). Here, in thin bodies, the pleura is very close to the œsophagus, and the thoracic duct, lying on its left side, may occasionally be seen through the pleural membrane. Below the arch of the azygos vein the pleura clothes the right side of the œsophagus—and very often even a considerable portion of its posterior surface too, thus forming a deep recess behind it—almost as low down as the opening in the diaphragm. On the left side, below the level of the aortic arch, the pleura comes in contact with the gullet, only for a short distance, just above the diaphragm (Fig. 666, E).

Divisions.—Both a diaphragmatic (Jonnesco) and an abdominal part of the œsophagus are described. The **diaphragmatic portion**, said to be about half an inch in length (1 to 1·5 cm.), corresponds to the portion of the tube which lies in the œsophageal orifice (or canal) of the diaphragm. The plane of this orifice is very oblique or almost vertical, and its abdominal opening looks forwards and to the left, and but little downwards. Above and in front, where it is bounded either by the posterior edge of the central tendon or by a few decussating fibres of the muscular portion of the diaphragm, which meet behind the tendon, the œsophageal orifice has practically no length, and consequently the œsophagus here passes into the abdominal cavity immediately after leaving the thorax. At the sides and behind, on the other hand, the decussating bands from the two crura, which embrace the orifice, are so arranged that they turn a flat surface (not an edge) towards the opening, and thus, posteriorly and laterally, the orifice or canal is of some length; and on these aspects there is a portion of the tube in contact with the diaphragm for a distance of 1 to 1½ cm. But this contact takes place not around a horizontal line, but in a very oblique plane corresponding to that of the orifice. On the whole, it is perhaps more satisfactory not to describe a separate diaphragmatic portion, but to say that the œsophagus pierces the diaphragm very obliquely, and that at the sides and behind it is in contact with the walls of the orifice for a distance of half an inch or more.

The œsophagus, in passing through the orifice, is connected to its boundaries by a considerable amount of strong connective tissue, but it is extremely difficult, or impossible, to demonstrate any direct naked-eye connexion between the œsophageal muscular fibres and those of the diaphragm.

The anterior or right boundary of the œsophageal orifice, formed of fibres derived from both crura of the diaphragm, is strongly developed and prominent, and usually lies in the œsophageal groove, on the back of the left lobe of the liver, which groove is rarely due to the pressure of the œsophagus alone.

The **abdominal portion** of the œsophagus is very short, for immediately after piercing the diaphragm the tube expands into the stomach. However, when the empty stomach is drawn forcibly downwards, a portion of the front and left side of the tube, about half an inch in length (1 to 1·5 cm.), is seen, to which the above term is applied. This part is covered with peritoneum, derived from the great sac in front and on the left, whilst its right and posterior surfaces are

uncovered. It is generally described as lying against the œsophageal groove and the left lateral ligament of the liver in front, but it never actually comes in contact with the latter of these structures, which is attached to the upper surface of the left lobe of the liver by one edge, and to the diaphragm, over an inch in front of the œsophagus, by the other. As regards the former, the œsophageal groove of the liver is generally occupied by the prominent right margin of the œsophageal orifice of the diaphragm, and occasionally by the œsophagus as well. Possibly this margin is so strongly developed and so prominent in order that it may bear the pressure of the liver off the gullet, which otherwise would be interfered with in its dilatation during the passage of food.

When the stomach is fully distended the abdominal part of the œsophagus almost disappears, being absorbed into the stomach in its distension. Indeed, it is possible that it is in most cases an artificial production, due to the traction on the empty stomach (generally necessary to demonstrate it) pulling a part of the œsophagus from its lax diaphragmatic moorings down into the abdominal cavity.

Variations.—The chief anomalies found in the œsophagus are: (1) Annular or tubular constrictions; (2) diverticula, of which the most interesting—known as "pressure pouches"—are usually situated on the posterior wall close to its junction with the pharynx, and these sometimes require surgical interference; (3) doubling in part of its course; and (4) communications between the trachea and œsophagus.

Structure of the Œsophagus (Fig. 669).—The œsophageal wall is composed of three proper coats—(1) muscular, (2) submucous, and (3) mucous. In addition, it is surrounded by an outer covering of areolar tissue (tunica adventitia), by which it is loosely connected to the various structures related to it in its course. This loose covering permits of its free movement and of its increase in size, or of its diminution, during the act of swallowing.

The **muscular coat** (tunica muscularis) is composed of two layers—an outer of longitudinal, and an inner of circular fibres. The *longitudinal layer* is highly developed, and, unlike the condition usually found in the digestive tube, it is as stout as, or in places stouter than, the circular layer. Its fibres form along the greater length of the tube an even covering outside the circular layer, and below they are continued into the longitudinal fibres of the stomach. Above, near the upper end of the œsophagus, the longitudinal fibres of each side, separating at the back, pass round towards the anterior aspect, and form two longitudinal bands (Fig. 667), which run up on the front of the tube, and are attached by a tendinous band to the upper part of the back of the cricoid cartilage (Fig. 668).

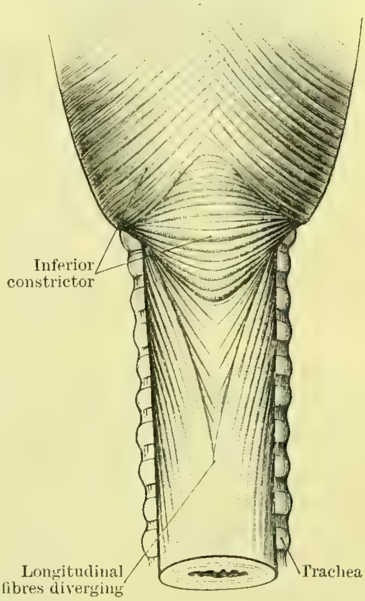


FIG. 667.—DISSECTION to show the arrangement of the muscular fibres on the back of the œsophagus and pharynx. Traced upwards, the longitudinal muscular fibres of the œsophagus are seen to separate behind; passing round to the sides, they form two longitudinal bands which meet in front above, and are united to the cricoid cartilage, as shown in the next figure.

The *circular muscular fibres*, though not forming such a thick layer as the longitudinal fibres, are nevertheless well developed. Below they are continued into both the circular and oblique fibres of the stomach. Above they pass into the lower fibres of the inferior constrictor of the pharynx.

The muscular fibres are entirely of the striated variety at the upper end of the œsophagus. Soon unstriped fibres begin to appear, increasing in number as we descend. In the lower half or two-thirds, only unstriped muscle is found.

The longitudinal fibres for about the upper fifth of the tube are entirely striped; in the second fifth striped and unstriped are mixed; whilst in the lower three-fifths unstriped fibres alone are present. The circular fibres are entirely striated for the first inch; after this unstriped fibres appear; and in the lower two-thirds, only unstriped muscles are found (D. J. Coffey).

The longitudinal fibres are often joined by slips of unstriped muscle, or elastic fibres, which spring from various sources, including the left pleura (constant, Cunningham), the bronchi, back of trachea, pericardium, aorta, etc. These slips assist in fixing the œsophagus to the surrounding structures in its passage through the thorax, and have been aptly compared to the tendrils of a climbing plant (Treitz).

The **submucous coat**, composed of areolar tissue, is of very considerable thickness, in order to allow of the expansion of the tube during swallowing. It connects the mucous

membrane loosely to the muscular coat, and admits of the former being thrown into folds when empty. In this coat are contained the numerous racemose mucous glands which open into the cavity of the œsophagus (Fig. 669).

The **mucous membrane** is of a greyish pink colour, much paler than that of the pharynx, and of a firm and resistant texture. It is covered by a thick stratified, squamous epithelium, on the surface of which the openings of numerous glands are found. Below, its junction with the gastric mucous membrane is indicated by a distinct, irregularly dentated or crenated line, which runs transversely round the tube. In carefully preserved specimens the smooth mucous membrane of the œsophagus above this line contrasts strongly with the mammillated gastric mucous membrane below.

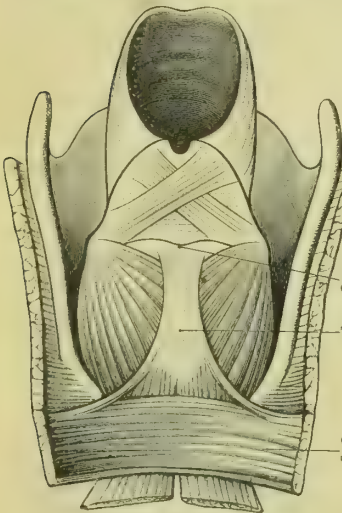


Fig. 668.—The Lower Part of the Pharynx and the Upper Part of the Œsophagus have been slit up from behind, and the mucous membrane removed to show the muscular fibres. The two longitudinal bands are seen coming round to the front to be attached by a common tendon to the upper border of the cricoid cartilage. See explanation of last figure.

Owing to the inelasticity of this coat, and the fact that it is but loosely connected to the muscular coat by the submucosa, it is thrown into a series of longitudinal folds when the œsophagus is empty and contracted; hence the stellate lumen often seen in sections of the gullet.

Glands. — Numerous racemose mucous glands, large enough to be distinctly seen with the naked eye, are found in the submucosa. They are pretty evenly distributed over the whole tube, and do not appear to be more numerous towards either end (Coffey). In addition to these, other glands, resembling closely those of the cardiac end of the stomach, are found in the mucous membrane of certain portions of the œsophagus. They are entirely confined to the mucosa, and do not extend beyond the muscularis mucosæ. These glands are specially numerous at both the upper and lower ends of the tube (Coffey, Schäfer).

Vessels and Nerves.—Its **arteries** consist of numerous small branches derived, in the neck, from the inferior thyroid, in the thorax, from the bronchial arteries and thoracic aorta, and in the abdomen, from the coronary artery of the stomach, and also from the left phrenic.

The **veins** form a plexus on the exterior of the œsophagus, from which branches pass, in the lower part of the tube, to the coronary vein of the stomach, and, higher up, to the azygos, and thyroid veins. There is thus established on the lower part of the œsophagus a free communication between the portal and systemic veins.

The **lymphatics** pass to the inferior set of deep cervical glands in the neck, and to the posterior mediastinal glands, many of which, of large size, are seen around the tube, in the thorax.

The **nerves** are derived from the recurrent laryngeal, and from the cervical sympathetic in the neck, from the pneumogastrics and sympathetic in the thorax.

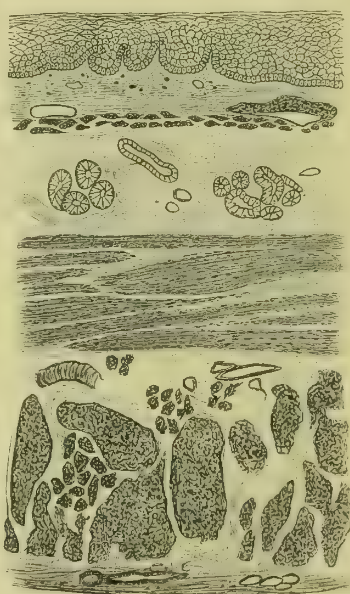


Fig. 669.—Structure of the Œsophagus, transverse section (after Horsley).

Development of the Œsophagus.

The œsophagus is developed from the portion of the foregut lying between the pharynx and the dilatation which represents the future stomach. At first, owing to the flexure of the head on the trunk in the early embryo, it is relatively short, but, as the neck is developed, it gradually becomes elongated and cylindrical.

The superficial epithelial cells are ciliated and somewhat cylindrical between the fourth and eighth months of fœtal life (Neumann); subsequently the adult condition is established.

THE ABDOMINAL CAVITY.

As the remaining parts of the digestive system lie within the abdomen it will be necessary to describe that cavity as a whole, and to refer briefly to its lining membrane—the peritoneum—before passing on to the consideration of the viscera which are contained within it.

The **abdomen** is that portion of the cavity of the trunk which lies below the diaphragm. It is the largest of all the cavities of the body, and contains the greater part of the digestive, urinary, and generative systems of organs, in addition to numerous vessels, nerves, and other structures.

Shape.—In general, the abdominal cavity is of a somewhat oval form, with the long axis directed vertically, and the wide end upwards. It is strongly flattened from before backwards, and is encroached upon in the middle line posteriorly by the projection forwards of the vertebral column, on each side of which it presents the appearance of a deep wide groove.

Boundaries.—The cavity is limited *above* by the concave vault of the diaphragm, which is dome-shaped and divided into a right and a left cupola by an intervening depression. Into the right cupola fits the greater part of the liver; in the left lie the stomach and spleen. On the upper surface of each cupola is placed the base of the corresponding lung, whilst between them, on the depression, rests the under surface of the heart.

During expiration, the right cupola ascends almost to the level of the right nipple; it is highest at a point about one inch internal to the nipple line, and here it reaches the upper border of the fifth rib, or even the middle of the fourth intercostal space. On the left side it is one-half to one inch (12-25 mm.) lower, and in the middle line it crosses the inferior extremity of the gladiolus about the level of the sixth rib cartilage.

Below, the cavity is limited by the pelvic floor, formed by the levatores ani, and coccygei muscles, covered on their upper surface by the pelvic fascia. The *anterior wall* is formed by the aponeuroses of the three flat abdominal muscles, together with the two recti, which latter constitute powerful braces for the wall, on each side of the middle line. The *lateral walls* are formed by the muscular portions of the obliqui and transversales muscles, and by the iliac bones with the iliacus muscles below.

Finally, the cavity is limited *behind* by the lumbar portion of the vertebral column with the psoas muscle on each side, and the quadratus lumborum still further out. The iliac bones also take part in the formation of the posterior wall inferiorly.

The upper portion of the cavity lies under cover of the ribs, which afford considerable protection to this part of the abdomen, particularly at the sides and behind, in which latter position the cavity is further protected by the vertebral column. Anteriorly, on the other hand, the ribs are wanting below the sternum, and here, the abdominal wall is formed only of aponeuroses and muscles. But even at the sides and back there is a considerable zone, usually one to two inches wide (Cunningham), between the lower ribs above and the crest of the ilium below, which has no bony support except that afforded by the vertebral column.

Whilst the circumference of the diaphragm is attached to the lower part of the thoracic framework in front and at the sides, and to the lumbar vertebræ behind, the central portion of the dome, on the other hand, namely, the central tendon, is placed high up, under cover of the ribs, and in a more or less horizontal plane. As a result, the peripheral muscular part slopes almost vertically upwards from the circumference of the thoracic framework to the central tendon, and lies for a considerable distance in contact with the deep surface of the ribs; thus the diaphragm comes to form, not only the roof of the cavity, but it also enters into the formation of the lateral, posterior, and, to a less extent, of the anterior walls; and almost as much of the cavity of the abdomen as of the thorax lies under cover of the ribs.

Owing to the fact that the boundaries of the abdomen are formed chiefly of muscles, it follows that its walls are capable of contraction to a greater or less degree, and the size of the cavity can consequently be altered in all directions. Its chief changes in form, however, are due to the descent or elevation of the diaphragm, the contraction or relaxation of the anterior and lateral walls, and the raising or lowering of the pelvic floor.

Within the muscles forming its walls, the abdomen is lined by **fasciæ**, which

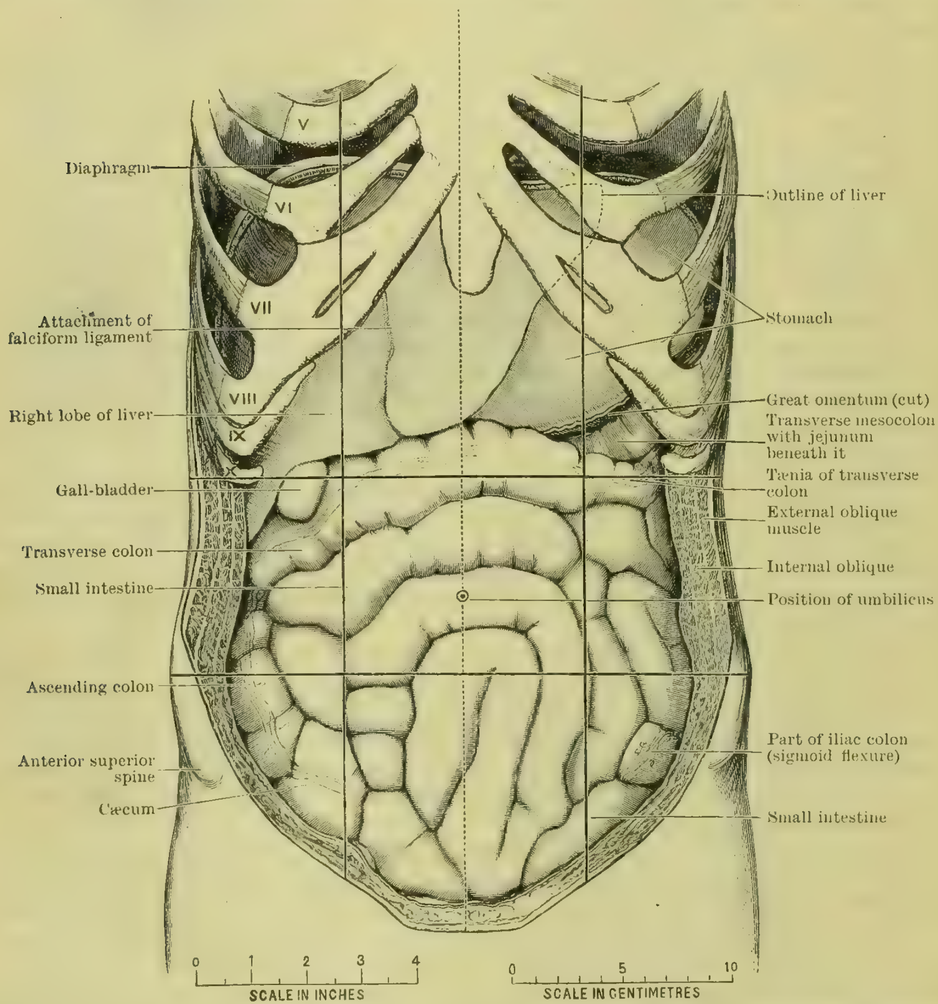


FIG. 670.—THE ABDOMINAL VISCERA IN SITU, as seen when the abdomen is laid open and the great omentum removed (drawn to scale from a photograph of a male body aged 56, hardened by formalin injections).

The ribs on the right side are indicated by Roman numerals; it will be observed that the eighth costal cartilage articulated with the sternum on both sides. The subcostal, intertubercular, and right and left Poupart lines are drawn in black, and the mesial plane is indicated by a dotted line. The intercostal muscles and part of the diaphragm have been removed, to show the liver and stomach extending up beneath the ribs. The stomach is moderately distended, and the intestines are particularly regular in their arrangement.

separate the muscles from the extraperitoneal connective tissue and peritoneum. These fasciæ are—(1) the *transversalis fascia* on the anterior and lateral walls, lining the deep surface of the transversalis muscle and continuous above with the fascia clothing the under surface of the diaphragm; (2) the *iliac fascia* on the posterior wall, covering the psoas and iliacus muscles; (3) the anterior layer of the *lumbar aponeurosis,* also on the posterior wall covering the front of the quadratus lumborum; and (4) the *pelvic fascia,* lining the pelvis.

Apertures.—Certain apertures are found in the walls of the abdomen, some of which lead to a weakening of the parietes. These are: the three openings in the

diaphragm for the passage of the inferior vena cava, the œsophagus, and the aorta respectively; the apertures in the pelvic floor, through which the rectum, the urethra, and the vagina in the female, reach the surface; the inguinal canal, through which the spermatic cord (or round ligament) passes, in leaving the abdominal cavity; and lastly, the crural canal, a small passage which runs down from the abdomen along the inner side of the femoral vessels. The two latter constitute on each side two weak points in the abdominal wall, through which a piece of intestine occasionally makes its way, giving rise to inguinal or femoral hernia respectively.

Extraperitoneal or **Subperitoneal Connective Tissue** (tela subserosa).—Between the fasciæ which cover the deep surfaces of the abdominal muscles, and the peritoneum which lines the cavity, there is found a considerable quantity of connective tissue, generally more or less loaded with fat, which is known as the extraperitoneal or subperitoneal connective tissue. This is part of an extensive fascial system which lines the whole of the body cavity, outside its various serous sacs, and is continued on the several vessels, nerves, and other structures which pass from these cavities into the limbs and neck.

In the abdomen it is divisible into a parietal and a visceral portion, both composed of loose connective tissue. The former lines the cavity, whilst the latter passes forwards between the mesenteries and other peritoneal folds to the viscera. These two portions of the extraperitoneal tissue are perfectly continuous with one another, and contain in their whole extent a vascular plexus, through which a communication is established between the vessels of the abdominal wall, on the one hand, and those of the contained viscera on the other.

The *parietal portion* is thin and comparatively free from fat over the roof and anterior wall of the abdomen, and here the peritoneum is more firmly attached than where the tissue is fatty and large in amount. In the pelvis, on the other hand, the tissue is loose and fatty, and, as such, it is continued up for some inches on the anterior abdominal wall above the pubes, to permit of the ascent of the bladder during its distension, and the attendant stripping of the peritoneum off this portion of the anterior abdominal wall. Here also the urachus and the obliterated hypogastric arteries will be found passing up in its substance. On the posterior wall the tissue is large in amount and fatty, particularly where it surrounds the great vessels and kidneys.

From this latter portion especially, the *visceral expansions* are derived in the form of prolongations around the various branches of the aorta. These expansions are connected with the areolar coats of the blood-vessels and are conducted by them into the mesenteries and other folds of the peritoneum, and thus reach the viscera.

The chief uses of this tissue are: (1) to unite the layers of the abdominal wall together; (2) to connect the viscera to these walls and to one another in such a loose manner that their distension or relaxation may not be interfered with, which would not be the case if the connecting medium were firm or rigid; (3) in addition, it is a storehouse of fat, forms sheaths for the vessels and nerves, and establishes, through its vascular plexus, communication between the parietal vessels and those distributed to the abdominal viscera.

Subdivision of the Abdominal Cavity.

The abdomen is divided *naturally* by the pelvic brim into two parts, the **abdomen proper,** and the cavity of the **pelvis.** The former of these is further subdivided, *artificially,* into nine regions.

The **pelvic brim** (Figs. 158 and 159, p. 214), which separates the two natural divisions of the cavity, is formed behind by the base of the sacrum, at the sides by the iliopectineal lines, and in front by the pubic crests. In the erect position it usually makes an angle of about 55 to 60 degrees with the horizontal. The two portions of the abdominal cavity which the brim separates meet at an angle, the abdomen proper running almost vertically upwards from it, whilst the pelvic cavity slopes backwards and downwards.

The **pelvic cavity** is bounded in front and at the sides by the portions of the innominate bones below the level of the iliopectineal lines. These bony walls are partly clothed, in front and laterally, by the obturator internus muscles, and internal to these by the parietal portion of the pelvic fascia, as low down as the white line. The posterior

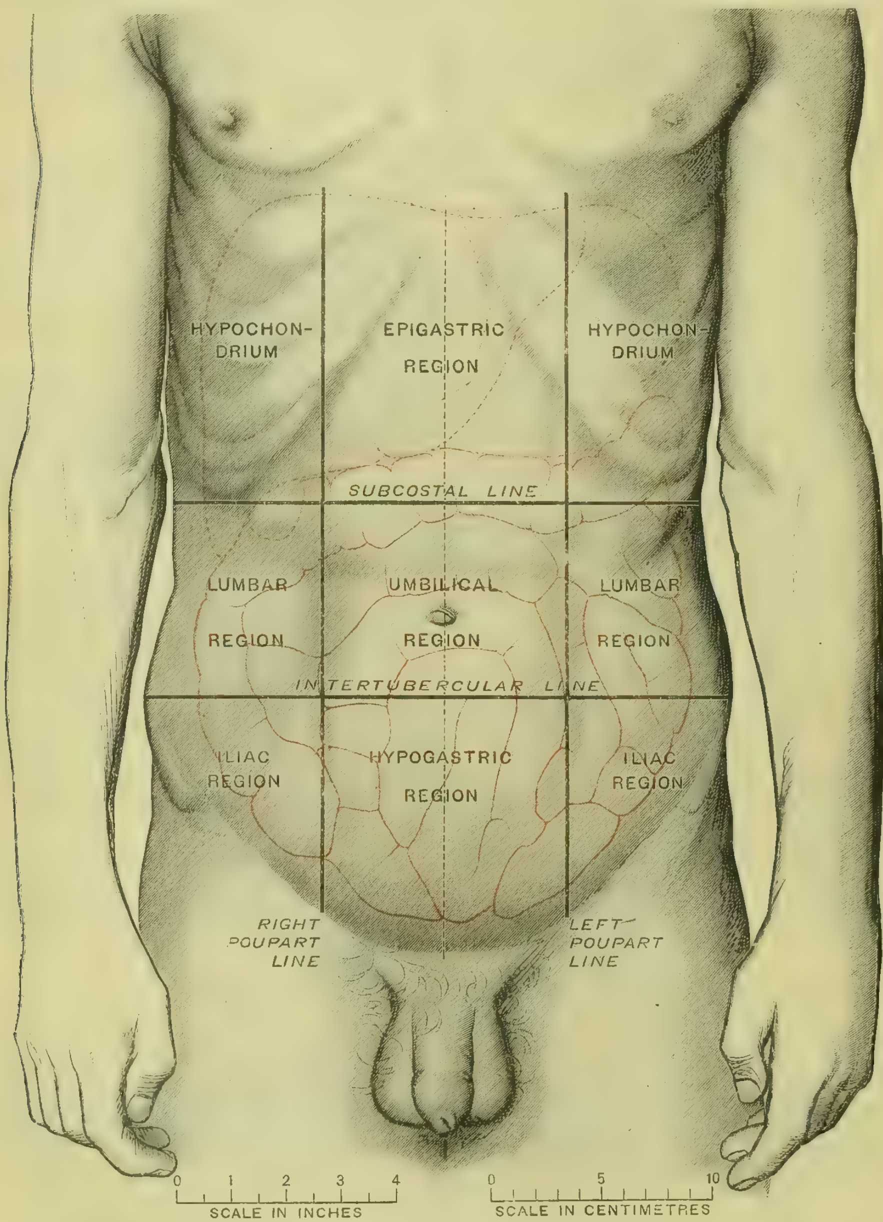


Fig. 671.—The Front of the Body, showing the subdivisions of the abdominal cavity and the position of the chief viscera. (From a photograph of the body represented in the preceding figure.) The viscera in Fig. 670 have been traced in red on this figure. The photographs for these two figures and for Fig. 675 were taken from the same body, under precisely similar conditions; consequently the relations of the deeper parts to the surface are correctly obtained by superimposing the pictures as in this illustration. The liver occupies a slightly lower position than usual.

wall is formed by the front of the sacrum, covered on each side by the pyriformis muscle. This wall (as represented by the pyriformis muscles) meets the lateral wall at the anterior border of the great sciatic foramen; through this foramen the pyriformis passes out, thus closing up what would otherwise be a large aperture in the parietes of the cavity. The floor is composed of the two pairs of muscles which form the pelvic diaphragm, namely, the levatores ani and coccygei—covered by the visceral layer of the

pelvic fascia. These muscles pass on each side, from the lateral wall of the pelvis, downwards and inwards towards the middle line, and present a concave upper surface towards the pelvic cavity.

Subdivision of the Abdomen Proper.—Owing to the large size of the cavity, and in order to localise more correctly the position of the various organs contained within it, the abdomen proper is artificially subdivided by two horizontal and two vertical lines (Fig. 671) drawn on its anterior wall. From these lines imaginary planes are supposed to be continued backwards, which divide up the cavity into nine regions.

Of the two *horizontal lines*, one is drawn around the trunk at the level of the lower border of the tenth costal cartilage; this is known as the **subcostal line,** and the imaginary plane corresponding to it, as the **subcostal plane.** The second horizontal line is drawn at the level of the highest point of each iliac crest, visible from the front; this point corresponds to the tubercle seen on the outer lip of the crest, about two inches behind the anterior superior spine, and can be easily located; the line and plane are consequently known as the **intertubercular line** and **plane** respectively.

The vertical lines are drawn, one on each side, perpendicularly upwards from a point on Poupart's ligament midway between the anterior superior spine and the symphysis pubis. These lines and the corresponding planes are known as the **Poupart lines** and **planes** respectively.

By the two horizontal lines the abdomen is divided into *three zones*, an upper or **costal,** a middle or **umbilical,** and a lower or **hypogastric zone.** By the two perpendicular lines each of these is subdivided into three parts, a central and two lateral. Thus, in the upper zone, we get a **hypochondriac region** or **hypochondrium** on each side, and an **epigastric region** or **epigastrium** in the centre. Similarly, the umbilical zone is divided into **right** and **left lumbar regions,** with an **umbilical region** between. And the hypogastric zone has a **hypogastric region** or **hypogastrium** in the centre, with **right** and **left iliac regions** at the sides.

In addition, the portion of the abdominal wall above the pubis is known as the *pubic region,* and that immediately above Poupart's ligaments, as the *inguinal region.*

The three central divisions, namely, the epigastric, umbilical, and hypogastric regions, can conveniently be further subdivided by the mesial plane, passing through the middle of the body, into right and left halves.

The upper horizontal, or subcostal, plane passes behind, through the upper part of the third lumbar vertebra, or the disc between the second and third lumbar vertebræ. The intertubercular plane cuts through the middle or upper part of the fifth lumbar vertebra.

The lower margin of the tenth costal cartilage frequently corresponds to the most dependent part of the thoracic framework. Often, however, the eleventh costal cartilage descends $\frac{1}{4}$ to $\frac{1}{2}$ inch lower. Nevertheless, the tenth cartilage is selected in drawing the subcostal plane, for two chief reasons, namely, it is visible from the front as a rule, and it is comparatively fixed, whilst the eleventh, being a floating rib, is much more movable, is variable in length, and more difficult to locate.

Contents of the Abdomen.—The following structures are found within the abdominal cavity :—

1. The greater part of the *alimentary canal*, viz. stomach, small intestine, and large intestine.
2. *Digestive glands:* the liver and pancreas.
3. *Ductless glands:* the spleen and the two suprarenal bodies.
4. *Urinary apparatus:* the kidneys, ureters, bladder, and part of urethra.
5. The internal *generative organs* according to the sex.
6. *Blood* and *lymph vessels*, and *lymphatic glands.*
7. The abdominal portion of the cerebro-spinal and sympathetic *nervous systems.*
8. Certain *fœtal remains.*
9. The *peritoneum*—the serous membrane which lines the cavity, and is reflected over most of its contained viscera.

THE PERITONEUM.

The arrangement of the peritoneum is so complicated, and its relations to the abdominal contents so intricate and detailed, that it will be expedient to postpone

its complete description until the various organs, with their special peritoneal relations, have been separately considered. Nevertheless, it will be necessary to give here a general account of the disposition of the membrane, and to refer to the three varieties of folds which it forms in passing from organ to organ, or from these to the abdominal wall.

The **peritoneum** (tunica serosa) is the serous sac which lines the abdominal cavity and invests most of the abdominal viscera, to a greater or less degree. Like the pleuræ, the tunica vaginalis of the testicle, and other serous sacs, its walls are composed of a thin layer of fibrous tissue, containing numerous elastic fibres, and covered over on the side turned towards the cavity of the sac by flattened endothelial cells. Like them, too, the peritoneum in the male is a completely closed bag, but in the female this is not the case, for the abdominal end of each Fallopian tube opens into the sac, whilst the other end of that tube communicates with the uterus, and thus, indirectly, with the exterior. Normally the membrane secretes only sufficient moisture to lubricate its surface, otherwise the sac is perfectly empty, and its opposing walls lie in contact, thus practically obliterating its cavity.

The use of these lubricated and highly polished serous linings, found in the abdomen and certain other cavities, is to facilitate, and render, as far as possible, frictionless, the movements of the contained viscera during any changes in size or form which they or their containing cavity may undergo. As a result of this arrangement, notwithstanding the tonic pressure of the abdominal wall on its contents, the stomach and intestines are free to move with the greatest ease and the least friction, when any change takes place either in the organs themselves or in their surroundings.

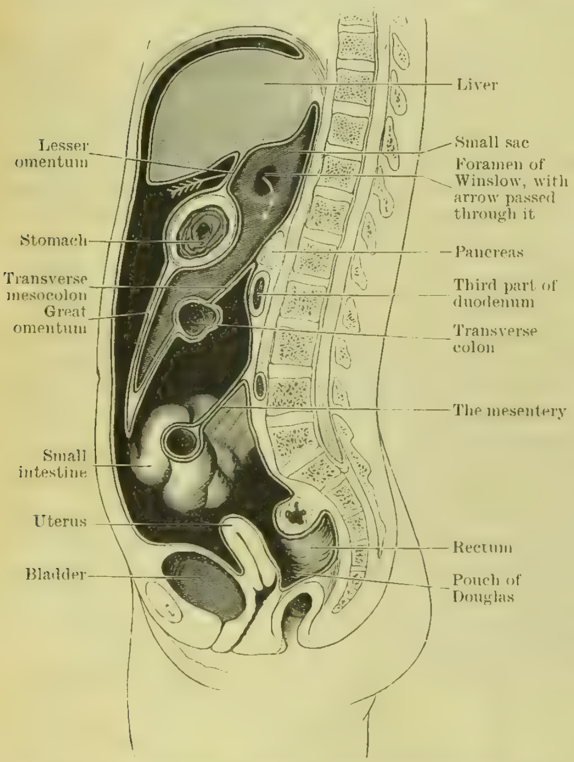


Fig. 672.—Diagrammatic Mesial Section of Female Body, to show the peritoneum on vertical tracing. The great sac of the peritoneum is black and is represented as being much larger than in nature; the small sac is very darkly shaded; the peritoneum on section is shown as a white line; and a white arrow is passed through the foramen of Winslow from the great, into the small sac.

The peritoneum is a thin glistening membrane, which may aptly be compared to a coat of varnish applied to the inner aspect of the abdominal walls, and to the surface of the contained viscera, except where these are directly applied to the walls or to one another. It forms throughout its entire extent a continuous and distinct sheet, but it is united so intimately to the viscera, and follows the irregularities of their walls so closely, that it appears at first sight to be a superficial layer of these walls, rather than a separate membrane. Outside the peritoneum lies the subperitoneal connective tissue—already described—which connects it more or less intimately to the fascial lining of the abdominal walls, and to the abdominal viscera.

If we trace the peritoneum as a continuous layer, beginning in front we find that it lines the deep surface of the anterior abdominal wall, and is continued upwards to the under surface of the diaphragm (Fig. 672), the greater portion of which it covers. From the posterior part of the diaphragm it is reflected or carried forwards on to the upper surface of the liver, and then down over the

stomach, intestines, and other abdominal viscera—clothing them all—to the pelvis. In like manner, when traced laterally from the anterior wall, the membrane will be found to line the sides of the cavity, and passing backwards to clothe the posterior abdominal wall, and the viscera lying upon it (Fig. 673, B). It should be pointed out that all the abdominal viscera are either directly fixed by connective tissue to the posterior abdominal wall, or suspended by blood-vessels from it. In the former case the peritoneum is reflected directly from the wall on to the viscera; in the latter it runs along the blood-vessels to reach the viscera, which it clothes, and then returns to the wall on the opposite sides of the vessels, which it thus encloses in a fold.

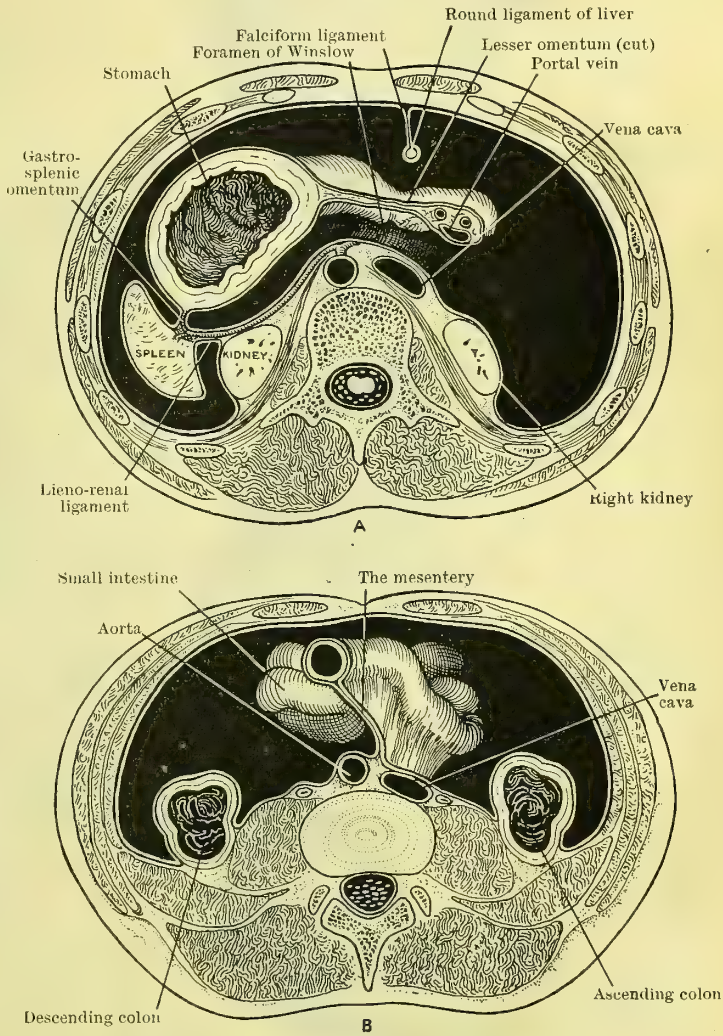


Fig. 673.—Diagrammatic Transverse Sections of Abdomen, to show the peritoneum on transverse tracing. A, at level of foramen of Winslow; B, lower down. In A note, one of the vasa brevia arteries passing to the stomach between the layers of the gastro-splenic omentum, and also the foramen of Winslow leading into the lesser sac which lies behind the stomach.

Whilst the main sac of the peritoneum lies in front of the various abdominal viscera, covering them over and dipping down between them, it should be mentioned that there is a special diverticulum derived from this "great sac," which turns in behind the stomach, and covers its posterior surface; this is known as the lesser or smaller sac, and it will be described in detail later on. The aperture through which one sac communicates with the other is termed the *foramen of Winslow*.

In passing from organ to organ, or from these to the abdominal wall, the peritoneum forms numerous folds, which are divided according to their connexions into three classes:—

(*a*) **Omenta** are folds of peritoneum which pass from the stomach to other abdominal organs. They are three in number, namely: (1) The *great* or *gastro-colic omentum*, which hangs down like an apron from the great curvature of the stomach, and passes to the transverse colon, connecting this latter, very loosely, however, to the stomach; (2) the *lesser* or *gastro-hepatic omentum*, which extends from the lesser curvature of the stomach to the liver; and (3) the *gastro-splenic omentum*, which passes from the stomach to the spleen.

(*b*) **Mesenteries** are folds of peritoneum which unite portions of the intestine to

the posterior abdominal wall, and convey to them their vessels and nerves. There are several mesenteries, *e.g.*, the *mesentery proper*, which connects the jejunum and ileum to the posterior abdominal wall, the *transverse mesocolon*, the *pelvic* (or "*sigmoid*") *mesocolon*, and occasionally others.

(*c*) **Ligaments** are peritoneal folds which pass between abdominal viscera other than portions of the digestive tube, or connect them to the abdominal wall. As examples of these may be mentioned most of the ligaments of the liver, the so-called "false ligaments" of the bladder, and the broad ligaments of the uterus.

This term is also applied to several small folds which connect portions of the intestinal tube to the parietes, but do not convey to them their vessels and nerves. The gastro-phrenic and phreno-colic ligaments are examples of these.

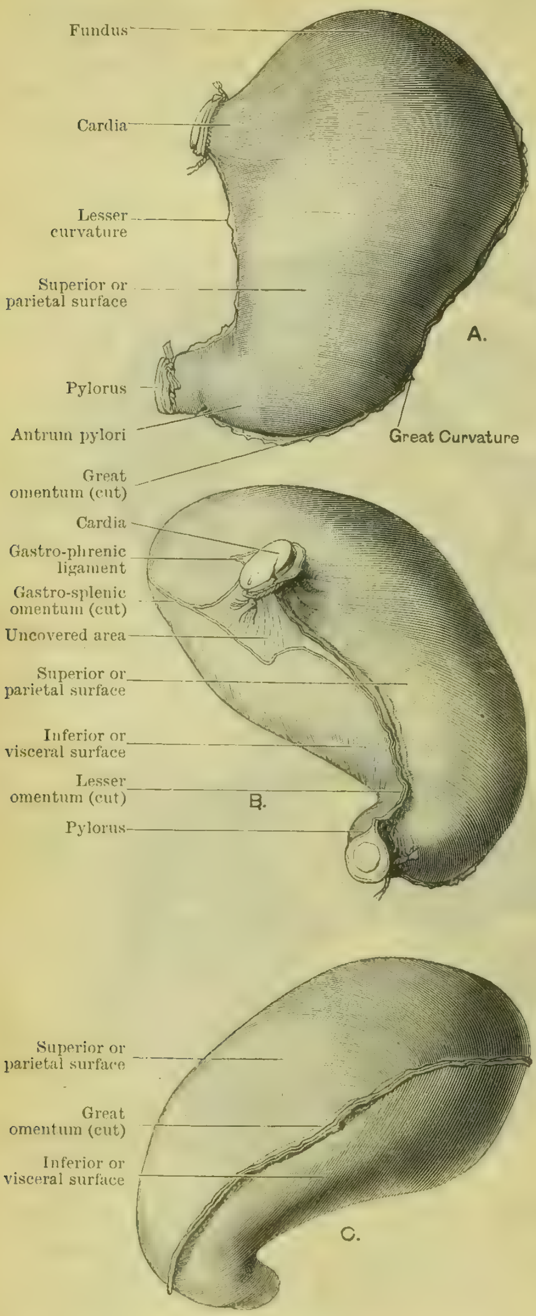


FIG. 674.—MODERATELY DISTENDED STOMACH, viewed, A, from front; B, from inner or right side; and C, from the outer or left side. (From photographs of the stomach shown in Figs. 670 and 675. The contents of the stomach were carefully removed through an artificial opening, and replaced with gelatine, the stomach remaining *in situ* throughout the operation. After the jelly hardened, its exact orientation was carefully noted, and pins indicating the vertical, horizontal, and transverse planes, having been inserted, the organ was removed and photographed.)

THE STOMACH.

The **stomach** (ventriculus) is the large dilatation found on the digestive tube immediately after it enters the abdomen (Figs. 674 and 675). It constitutes a receptacle, in which the food accumulates after its passage through the œsophagus, and in it take place some of the earlier processes of digestion, resulting in the conversion of the food into a viscid soup-like mixture, known as chyme. The chyme as it is formed is allowed to escape intermittently through the pylorus, into the small intestine, where the digestive processes are continued.

Although the form of the stomach varies considerably under different conditions, in general it is of an irregularly pyriform shape, with a wide or cardiac end directed backwards and to the left, and a narrow pyloric end which runs to the right to join the duodenum. In addition to (*a*) its *two ends*, the stomach presents for examination the following parts: (*b*) *two curvatures*, greater and lesser, separating (*c*) *two surfaces*, superior and inferior; and (*d*) *two orifices*, the œsophageal orifice or cardia, and the pyloric orifice or pylorus (Fig. 674).

Position and Form of the Stomach.—*When empty*, or nearly so, the stomach lies in the left hypochondrium and left part of the epigastrium, with its wide end

or fundus directed backwards towards the diaphragm, its long axis lying almost in a horizontal plane, and its pyloric portion running to the right to join the duodenum. In this state the whole organ is narrow and attenuated, particularly the pyloric portion, which is contracted, and resembles a piece of thick-walled small intestine.

When distended, the organ assumes the form of an irregular pear, and both the cardiac and pyloric portions become full and rounded (Fig. 674). It still lies within the hypochondriac and epigastric regions; but in extreme distension, or in exceptional cases, it may pass down below the subcostal plane and reach into the umbilical and left lumbar regions. As a result of the general increase in length which takes place during distension, the pylorus is moved a variable distance to

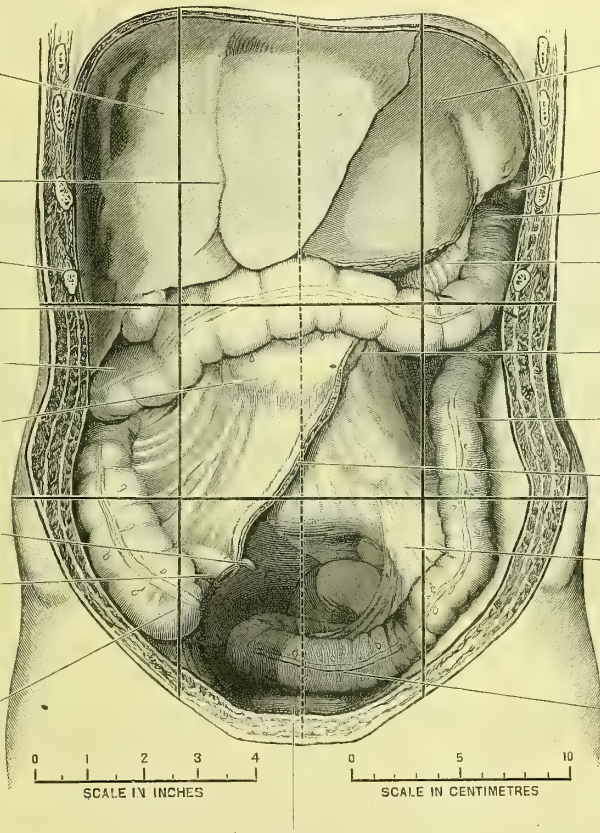


Fig. 675.—The Abdominal Viscera after the Removal of the Jejunum and Ileum (from a photograph of the same body as Fig. 670). The transverse colon is much more regular than usual. Both the liver and cæcum extend lower down than normal. The subdivisions of the abdominal cavity are indicated by dark lines.

the right beneath the quadrate lobe of the liver, and at the same time the long axis of the whole organ becomes much more oblique, running forwards, downwards, and to the right. Finally there is developed a special dilatation of the pyloric portion, known as the *antrum pylori*, which in extreme distension is carried so far to the right that it may even reach into the hypochondrium.

In brief, it may be said that the stomach when empty is contracted, not collapsed; that it assumes a narrow, attenuated shape, its cavity being practically obliterated, and its pyloric portion contracted to the size of small intestine; and in addition, that its long axis lies in an almost horizontal plane. With distension there comes a general enlargement of the various diameters, an elongation of the whole organ, with a consequent passage of its pyloric portion to the right beneath the liver, the development of the antrum pylori, and an inclination of its axis from behind downwards and forwards, without any rotation.

Natural Form of the Stomach.—As seen in male bodies the viscera of which have been hardened by the intravascular injection of formalin, the *empty stomach*, as already stated, presents an attenuated or slender pear-shaped appearance, and is sharply bent on itself, particularly at the junction of the cardiac and pyloric portions. As a rule it is somewhat flattened from above downwards in its cardiac portion, but preserves in its whole length, more or less, an irregularly rounded or cylindrical form. Its long axis is directed, in the cardiac portion, from behind forwards and to the right with a slight inclination downwards; then it bends almost at a right angle, and in the pyloric portion runs to the right towards the pylorus.

Even in the empty condition, the cardiac portion retains, as a rule, an appearance of rotundity, and never assumes a completely collapsed and flattened form; although it sometimes is very much contracted, and approaches the tubular form of the pyloric portion.

The collapsed, flat-walled, and flaccid bag, often pictured as the empty stomach, does not represent its true condition during life, but is rather the result of post-mortem softening, relaxation, and pressure. The stomach, like the bladder, and like other hollow viscera with muscular walls, is not an inert bag, but an extensile living organ capable of expansion and contraction, which adapts the size of its cavity to the amount of its contents. When food enters, it expands, the expansion being proportionate to the amount of food that enters; and when the food passes away or is absorbed, it contracts, until its cavity is reduced to little more than a stellate lumen.

In the gradual passage of the stomach from the empty to the distended condition we may recognise three stages. *First stage.*—This commences with an enlargement of the fundus, and is followed by an expansion of the whole cardiac portion, which passes upwards and also to the left towards the diaphragm, displacing the coils of the transverse colon, which lie here when the stomach is empty. The pyloric portion for 3 or 4 inches still remains contracted and cylindrical. In this condition the stomach is frequently found after death. *Second stage.*—As distension goes on the lesser curvature opens out, the pyloric portion (with the exception of its last inch) expands, but its junction with the cardiac portion usually remains distinct, until distension is almost complete. *Third stage.*—A further general expansion of the whole stomach takes place; the diameters of both cardiac and pyloric portions, as well as the length of the organ, are increased; and the great curvature presses forwards against the anterior abdominal wall in front, where the restraining influence of the ribs is absent. The pyloric end for about 1 inch (2·5 cm.) from the pylorus remains narrow (constituting the pyloric canal of Jonnesco), but to the left of this it bulges forward, forming the antrum pylori, which is most distinct at the great curvature. By the increase of the organ in length the antrum is carried a considerable distance to the right beneath the liver—even further than the pylorus itself—so that the terminal part of the stomach is bent backwards and to the left, in order to reach the pylorus, which latter very rarely passes more than one and a half or two inches to the right of its normal position, namely, in the empty condition, within half-an-inch (12 mm.) of the middle line. Finally, as it fills, the stomach becomes gradually more oblique, so that in the distended state the long axis of the posterior two-thirds of the organ is directed forwards, downwards, and to the right, and forms an angle of about 40° to 45° with both the horizontal and sagittal planes (Fig. 674), whilst its anterior third is still more oblique.

There is, however (as pointed out by Jonnesco), no distinct rotation of the organ on its long axis—no turning of the great curvature more forwards, nor of the so-called anterior surface more upwards.

In the change from the distended to the empty state these stages are reversed: the whole stomach is contracted, or drawn in, from all directions towards the lesser curvature; this latter is bent upon itself to an acute angle, and the long axis of the organ, becoming less oblique, approaches the horizontal.

Although this description of the shape and direction of the stomach is at variance with the generally accepted accounts, it is based upon the examination of a considerable number of specially-hardened bodies, and has been found to apply so generally, that it is advanced here as the condition most frequently found in the male immediately after death, and as, in all probability, giving a near approximation to the conditions present during life. It must, however, be admitted that, in the female, as a result of tight lacing, the stomach is often found to assume an abnormal vertical position; but this condition is associated with displacement of other abdominal organs in the neighbourhood, and cannot be looked upon as normal (see page 1007).

Size and Capacity of the Stomach.—Probably no organ in the body varies more in size within the limits of health than the stomach. Moreover, as its tissues change so rapidly after death, measurements made on softened and relaxed organs are not only worthless but quite misleading. Consequently it is difficult, perhaps impossible, to arrive at a correct estimate of its size and capacity.

The *length* of the stomach in the fully distended condition is about 10 or 11 inches (25 to 27·5 cm.), and its greatest *diameter* not more than 4 or 4½ inches (10 to 11·2 cm.); whilst its *capacity* in the average state rarely exceeds 40 ounces, or 1 quart.

The length has been estimated by different authorities at from 10 to 13½ inches (26 to 34 cm.); its diameter, from 3¼ to 6 inches (8 to 15 cm.); and its capacity from 1½ to 5 pints. The measurements of the capacity given by Dr. Sidney Martin are probably the most accurate: he states that the capacity varies between 9 and 59 oz., with an average of from 35 to 40, or a little over a litre.

The distance in a direct line from the cardiac to the pyloric orifice varies from 3 to 5 inches (7·5 to 12·5 cm.), and that from the cardia to the summit of the fundus from $2\frac{1}{2}$ to 4 inches (6·2 to 10·0 cm.).

As regards the *weight*, I have found the average of twelve wet specimens freed from their omenta to be $4\frac{3}{4}$ oz. (135 grms.), with a maximum of 7 oz. (198·45 grms.) and a minimum of $3\frac{1}{2}$ oz. (99·22 grms.). Glendenning gives the weight as $4\frac{1}{2}$ ounces.

Relations and Connexions of the Stomach.—The relations will be much more readily understood if we briefly consider the disposition of the portion of the abdominal cavity in which the stomach lies, a portion which has such constant and definite surroundings that it perhaps merits the title of "stomach chamber."

The **stomach chamber** (Figs. 676 and 677) is a space in the upper and left portion of the abdominal cavity which is completely occupied by the stomach when that organ is distended, but into which the transverse colon also passes, doubling up over the stomach, when this latter is empty.

The chamber presents an arched roof, an irregularly sloping floor, and an anterior wall. The *roof* is formed partly by the visceral surface of the left lobe of the liver, and in the rest of its extent by the left cupola of the diaphragm, which arches gradually downwards behind and on the left to meet the floor.

The *floor* or "*stomach bed*" (Fig. 676) is a sloping shelf on which the under surface of the stomach rests, and by which it is supported. The bed is formed behind by the top of the left kidney (with its suprarenal capsule) and the gastric surface of the spleen; in front of this, by the wide upper surface of the pancreas; and more anteriorly still, by the transverse mesocolon running forwards above the small intestine, from the anterior edge of the pancreas to the colon (Fig. 676), which latter completes the floor anteriorly.

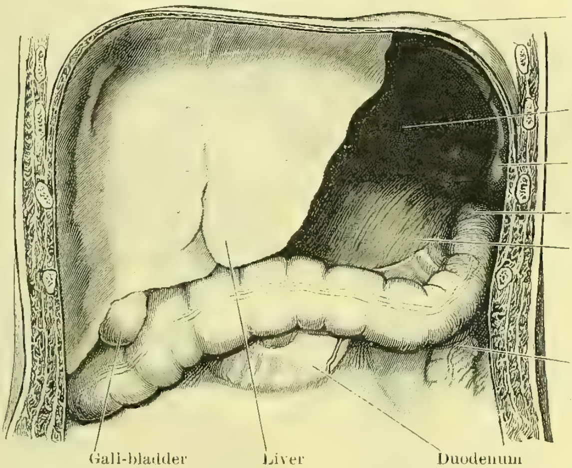


FIG. 676.—THE STOMACH CHAMBER AND STOMACH BED.

From the same body as the preceding figure, after the stomach had been removed.

Finally, the *anterior wall* of the stomach chamber is formed by the abdominal wall, between the ribs on the left and the liver on the right side.

This chamber is completely filled by the stomach, when that organ is distended. When, on the other hand, the stomach is empty and contracted, it still rests on the floor, or stomach bed, but occupies only the lower portion of the chamber, whilst the rest of the space is filled by the transverse colon, which turns gradually upwards as the stomach retracts, and finally comes to lie both above and in front of that organ and immediately beneath the diaphragm—a fact to be remembered in clinical examinations of this region.

The **upper** (or parietal) **surface of the stomach** is more convex and more extensive than the lower. It lies, when the organ is distended, in contact with the roof and anterior wall of the stomach chamber, and thus comes into relation with the under surface of the left lobe of the liver on the right, the vault of the diaphragm on the left, and the anterior abdominal wall in front (Fig. 670). When the stomach is empty, on the other hand, the transverse colon, as just explained, doubles up over it, and separates this surface from the roof of the chamber.

The **lower** (or visceral) **surface**, more flattened than the upper, rests upon the stomach bed, and comes into relation with the following parts:—Behind, at the fundus, with the diaphragm and gastric surface of the spleen; in front of this with the left kidney, the suprarenal, and the upper surface of the pancreas, and, more anteriorly still, with the transverse mesocolon and colon. From all of these the stomach is separated by the small sac of the peritoneum (the anterior layer of which clothes this surface), except below and to the left of the cardia, where the

peritoneum is absent, over an irregularly triangular area (Fig. 674), and here the stomach lies in direct contact with the diaphragm (sometimes also with the top of the left kidney and suprarenal capsule).

It should be pointed out that the under surface of the stomach is separated from the duodeno-jejunal flexure and the beginning of the jejunum by the transverse mesocolon only. By

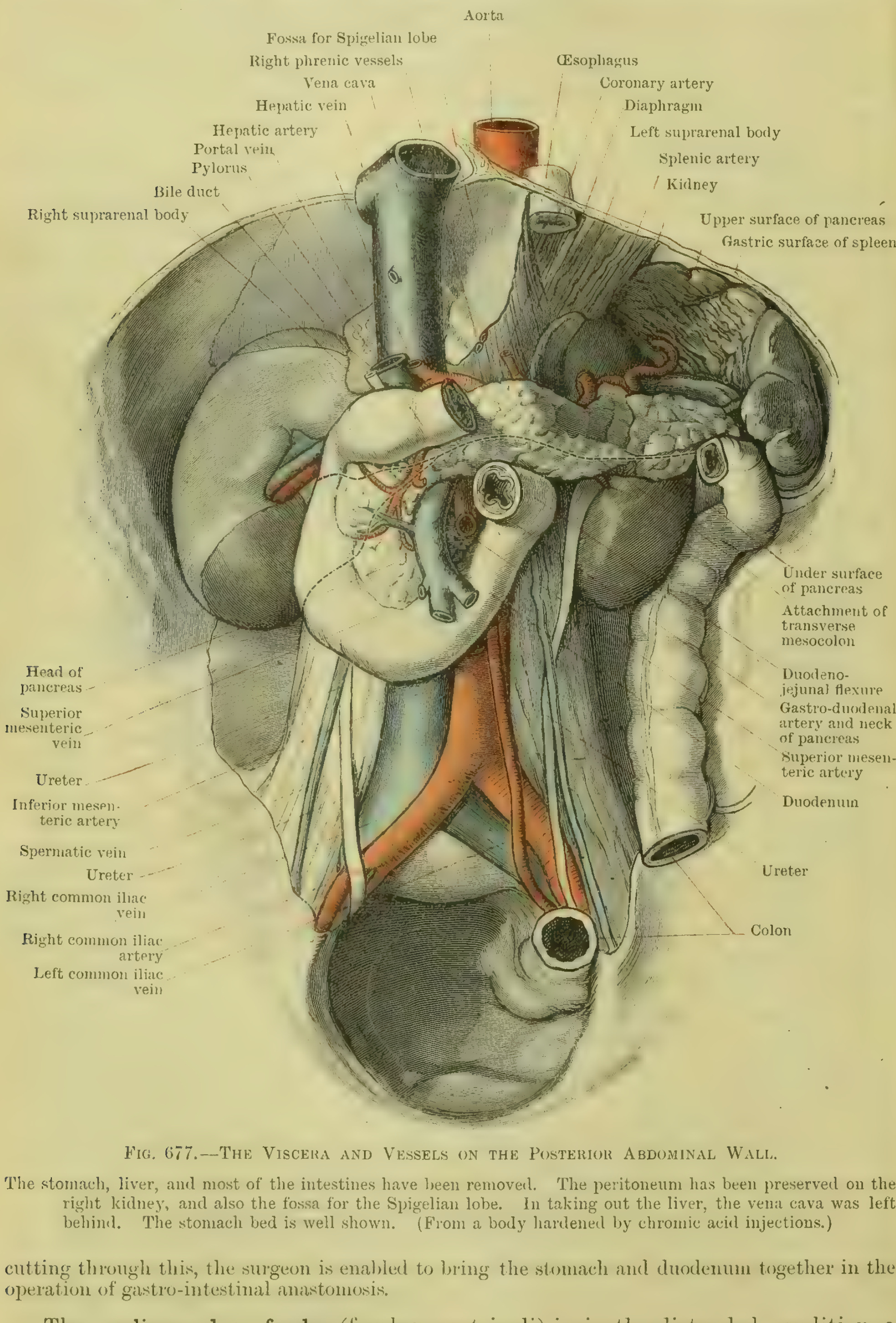


FIG. 677.—THE VISCERA AND VESSELS ON THE POSTERIOR ABDOMINAL WALL.

The stomach, liver, and most of the intestines have been removed. The peritoneum has been preserved on the right kidney, and also the fossa for the Spigelian lobe. In taking out the liver, the vena cava was left behind. The stomach bed is well shown. (From a body hardened by chromic acid injections.)

cutting through this, the surgeon is enabled to bring the stomach and duodenum together in the operation of gastro-intestinal anastomosis.

The **cardiac end** or **fundus** (fundus ventriculi) is, in the distended condition, a large rounded cul-de-sac, which projects backwards and upwards against the left

cupola of the diaphragm; opposite the œsophageal orifice it passes into the body of the stomach. Its surfaces are merely prolongations of the upper and lower surfaces of the organ, and accordingly its relations are similar.

Thus the upper surface lies against the left cupola of the diaphragm (and occasionally the left lobe of the liver, when this extends further than usual to the side); whilst the lower surface rests chiefly on the gastric surface of the spleen, and also on the left kidney.

The highest part of the fundus reaches to the level of a point on the chest wall about half-an-inch (12 mm.) internal to the apex point of the heart.

The **narrow** or **pyloric end**, when the stomach is empty, is contracted and cylindrical, and runs transversely to the right, lying as a rule beneath the left lobe of the liver. During distension it is carried to the right beneath the quadrate lobe, and its terminal part is there directed backwards in order to reach the duodenum. Even in this condition its last inch remains comparatively undistended.

The **lesser curvature** (curvatura ventriculi minor) is directed towards the liver, and corresponds to the line along which the lesser omentum is attached to the stomach, between the pyloric and œsophageal orifices (Fig. 674). It is connected to the liver by the lesser omentum, between the layers of which the gastric and pyloric vessels run along the curvature.

This curvature, when the stomach is empty, presents a sharp bend at the junction of the cardiac and pyloric portions, but when fully distended it forms an open curve except near its pyloric end, where it becomes convex, corresponding to the S-shaped form of this portion of the organ (see below). On viewing a distended stomach from the right side (Fig. 674, B), it will be observed that the line of the lesser curvature turns slightly on to the upper aspect in order to reach the cardia, which is situated rather on the upper surface than on the border of the stomach.

The **great curvature** (curvatura ventriculi major), which is usually over three times as long as the lesser curvature, corresponds to a line drawn from the cardia over the summit of the fundus (Fig. 674), and then along the line of attachment of the great omentum as far as the pylorus. In general, it is directed to the left and forwards, but at its beginning, near the cardia, it of course looks in the opposite direction. The great curvature corresponds in the greater part of its length to the attachment of the great omentum; and in close relation to it, but between the layers of the omentum, run the right and left gastro-epiploic vessels.

Antrum Pylori.—This is a prominence of the great curvature in the distended stomach, situated a short distance from the pylorus. When the stomach is distended, the pyloric portion, near its right extremity, becomes curved somewhat like the letter *S* placed horizontally. The first curve of the *S* is convex downwards and forwards, and this becoming more prominent with distension, forms a projection of the great curvature known as the antrum pylori. The terminal part of the *S* extends to the pylorus; it is about one inch (2·5 cm.) in length, and it appears never to become distended to any noticeable extent. This latter is the part described by Jonnesco as the pyloric canal.

The terms **cardiac** and **pyloric portions** are often employed to indicate the wider and narrower portions of the stomach respectively. The cardiac portion includes about two-thirds of the length of the whole organ; the pyloric portion the remaining third. Except in complete distension, the junction of the two is usually indicated by a slight constriction, and occasionally there is a thickening of the muscular fibres (apparently those of the oblique layer), corresponding in part to the constriction.

The **œsophageal orifice** or **cardia** is the aperture at which the gullet opens into the stomach. It is situated at the upper end of the lesser curvature, to the right of the fundus, and nearer the upper than the lower surface of the stomach (Fig. 674, B). The cardia is very deeply placed, and lies about four inches behind the sternal end of the seventh left costal cartilage, at a point one inch from its junction with the sternum. Posteriorly it corresponds to the level of the eleventh dorsal vertebra.

Owing to the fixation of the œsophagus by its passage through the diaphragm, and the close connexion between the stomach and the diaphragm, near the cardia where the peritoneum is absent, this is the most fixed part of the whole organ. The object of this immobility is evidently to maintain a clear passage for the food entering the stomach. The orifice is oval rather than round, with its long axis very oblique; and although the presence of a valvular arrangement at the cardia has been advocated by several authorities, it is difficult to find satisfactory proof of its existence in hardened bodies. It seems more probable, on the whole, that no such arrangement naturally exists here. On the other hand, the muscular margins of the œsophageal opening in the diaphragm, and the circular fibres of the lower end of the œsophagus,

which are particularly well developed, afford, by their simultaneous contraction, an effective means of closing the œsophagus immediately above the cardia, and thus of preventing regurgitation of the contents of the stomach.

The **pyloric orifice** or **pylorus** is the aperture through which the stomach communicates with the duodenum. It is marked on the surface by a slight constriction, most evident at the curvatures: and in the interior by a prominent thickening of the wall—the pyloric valve (valvula pylori)—produced by a special development of the circular muscular fibres, known as the pyloric sphincter (musculus sphincter pylori). When examined post-mortem in the ordinary way, the aperture, viewed from the duodenal side, is somewhat oval in form, and closely resembles the external os uteri (Cunningham). When seen from the opposite side, it presents an irregular or stellate appearance, owing to the fact that the rugæ of the gastric mucous membrane are continued up to the orifice.

The pylorus rests on the neck of the pancreas below and behind, and is overlapped by the liver above and in front. Its average position can be marked on the surface of the body by the intersection of two lines; one drawn horizontally halfway between the top of the sternum and the pubic crest (Addison), the other drawn vertically a little way (½ inch, 12 mm.) to the right of the middle line.

During the earlier stages of gastric digestion the sphincter pylori is strongly contracted and the aperture firmly closed, but it opens intermittently to allow of the passage of properly digested portions of the food. As digestion advances the sphincter probably relaxes somewhat; but in hardened bodies a really patent pylorus is rarely or never found, which would seem to indicate that the pylorus is normally closed, or nearly so, and that its opening is an active rather than a passive condition, as in the case of the anal canal.

As regards its size, the pylorus is stated to be about ½ inch (12·5 mm.) in diameter, but there is no doubt that this represents neither its full size nor the calibre of the valve when at rest. Foreign bodies with a diameter of ¾ to 1 inch have been known to pass through the pylorus without giving rise to trouble, even in children. On the other hand, when at rest, with an empty stomach and duodenum, the aperture, as seen in formalin-hardened bodies, is practically closed, and presents a stellate or purse-mouth appearance, viewed from either aspect. In hardened bodies with distended stomach and duodenum, the aperture, which is somewhat oval, is practically closed, and from the duodenal side resembles the external os uteri. But both in the empty and the distended condition of the stomach the pylorus seems to be rather a tubular narrowing, extending over at least ½ to 1 inch of the canal, than a sudden constriction.

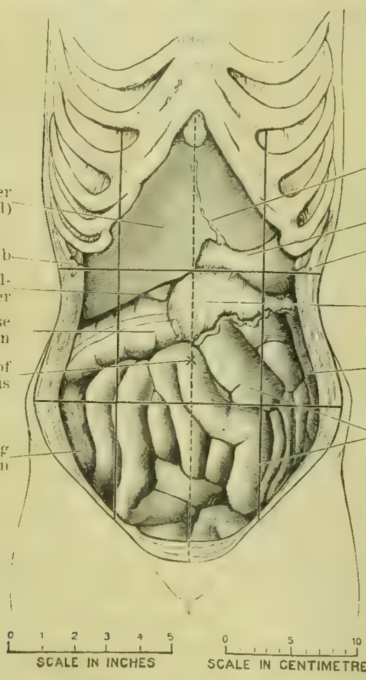


Fig. 678.—Abdomen of Female, showing Displacements resulting from Tight Lacing.

The liver is much enlarged, and extends on the left side to the ribs, where it was folded back on itself for over an inch. The pyloric end of the stomach and the beginning of the duodenum are quite superficial below the liver, and all the viscera are displaced downwards. (From a photograph of a body hardened by injections of formalin.)

When the stomach is empty the pylorus is usually placed near (*i.e.* within ½ inch, 12 mm. of) the middle line, beneath the left or sometimes the quadrate lobe of the liver, and at the level of the first lumbar vertebra, or the disc between this and the second lumbar. During distension it is pushed over beneath the quadrate lobe for a variable distance, but very rarely more than 1½ or 2 inches to the right of the middle line; and its orifice, instead of looking towards the right, is then directed backwards, for, as already explained, the antrum in distension is carried to the right in front of the pylorus, or even beyond it.

Peritoneal Relations.—The stomach is almost completely covered by peritoneum—the anterior surface being clothed by the posterior layer of the great sac, and the posterior surface by the

anterior layer of the small sac. From the lesser curvature the lesser omentum extends to the liver, whilst from the great curvature the great omentum passes down to the transverse colon. Higher up still, on the left, the continuation of the great omentum, namely, the gastro-splenic omentum, passes off (from the inferior surface, a little below the great curvature) to the spleen. Finally, a small peritoneal fold, known as the *gastro-phrenic ligament*, is found running from the stomach up to the diaphragm along the left side of the œsophagus.

A small, irregularly triangular, area (Fig. 674), about 2 inches wide and $1\frac{1}{2}$ inches from above downwards, during moderate distension of the stomach, on the inferior surface below and to the left of the cardia, is uncovered by peritoneum, and over it the organ is in direct contact with the diaphragm, occasionally also with the top of the left kidney and suprarenal. From the left angle of this "uncovered area" the attachment of the great omentum (gastro-splenic part) starts; and at the right angle the coronary artery passes on to the stomach.

In the child at birth the stomach is scarcely as large as a small hen-egg, and its capacity is about one ounce (28·3 grammes). In shape it corresponds pretty closely to that of the adult, and the fundus is well developed, although the contrary is often stated.

In the female (Fig. 678), as a result of tight lacing, the stomach is often displaced in position and distorted in shape, so that instead of running obliquely forwards, downwards, and to the right, it is placed nearly vertically along the left side of the vertebral column, in which direction it has a very considerable length. Its lower part bends rather suddenly, and runs upwards and to the right to join the pylorus, which is often placed quite superficially below the liver. As a result of the displacement, the left extremity of the pancreas is pushed downwards from the horizontal until it almost assumes a vertical position. The narrowing and inversion of the lower margin of the thoracic framework at the same time constricts the stomach about its middle, and often leads to a bilocular condition.

Hour-glass or Bilocular Stomach.—This is a condition of the organ, by no means rare, in which the stomach is more or less completely separated into two divisions—a cardiac and a pyloric—the normal arrangement in certain rodents and other animals. As a rule the former division is the larger, but occasionally the two are nearly equal, or the pyloric portion may exceed the cardiac in size. Sometimes the condition is temporary, and the result of a vigorous contraction of the circular muscular fibres at the seat of constriction. In other cases it is permanent, and may be due to pressure of the lower ribs, as from tight lacing, to cicatricial contraction after gastric ulcer, or possibly to a congenital or acquired thickening of the muscular fibres corresponding to the constriction. The condition is much more frequent in the female than the male, and is rarely found in the child.

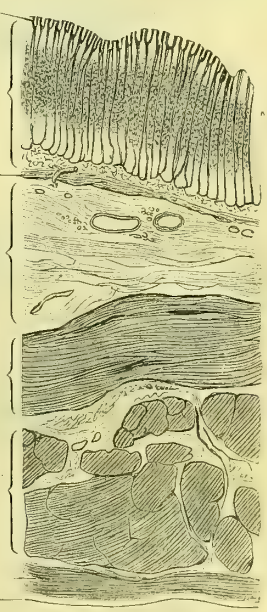


Fig. 679.—Section through Wall of Stomach, Cardiac Portion (slightly modified from Stöhr).

Structure of the Stomach.

The stomach wall is composed of four coats—namely, from without inwards: (1) peritoneal, (2) muscular, (3) submucous, and (4) mucous (Fig. 679).

Peritoneal or **Serous Coat** (tunica serosa).—This coat is formed of the peritoneum, the relations of which to the stomach have already been described. It is closely attached to the subjacent muscular coat, except near the curvatures, where the connexion is more lax; and it confers on the stomach its smooth and glistening appearance.

The **muscular coat**, which is composed of unstriped muscle, is thinnest in the fundus and body, much thicker in the pyloric portion, and very highly developed at the pylorus. It is made up of three incomplete layers—an external of longitudinal, a middle of circular, and an internal of oblique muscular fibres.

The *external layer* (stratum longitudinale) consists of longitudinal fibres, continuous with those of the œsophagus, on the one hand, and those of the duodenum on the other (Fig. 680, A). They are most easily demonstrated on the lesser curvature, where they can be traced down from the right side of the œso-

phagus. Over the great curvature and on the two surfaces they are present as an extremely thin and irregular sheet. Towards the pylorus the longitudinal fibres grow much thicker, and also much tougher and more closely united, but they do not take any part in the formation of the pyloric valve.

A specially-condensed band of these can be often made out both on the front and back at the antrum pylori, the form of which is said to be due to their presence. These bands are known as the pyloric ligaments (ligamenta pylori).

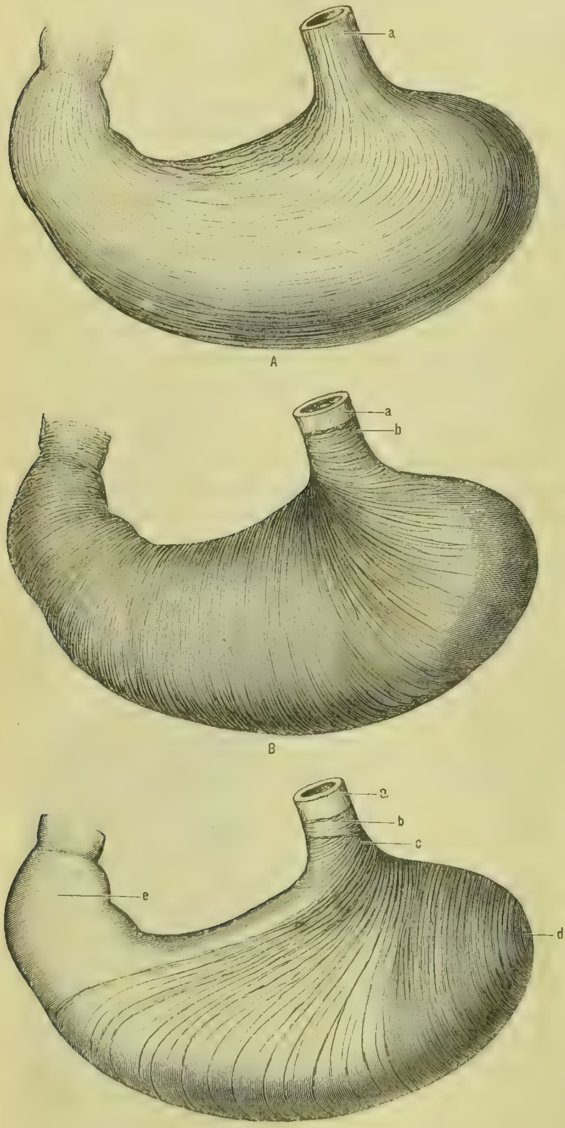


FIG. 680.—THE THREE LAYERS OF THE MUSCULAR COAT OF THE STOMACH. A, Outer or longitudinal layer ; B, Middle or circular layer ; C, Internal or oblique layer. *a*, Longitudinal fibres of œsophagus ; *b*, Superficial circular fibres of œsophagus passing into circular fibres of stomach in B ; *c*, Deep circular fibres of œsophagus passing into oblique fibres of stomach in C ; *d*, Oblique fibres forming rings at the fundus ; *e*, Submucosa.

The *middle layer* (stratum circulare) is composed mainly of circular fibres, continuous with the more superficial of the circular fibres at the lower end of the œsophagus (Fig. 680, B). They do not commence as a series of circular bundles surrounding the fundus, as usually described. On the contrary, they begin as a set of U-shaped bundles which loop over the lesser curvature at the right of the cardia, and pass downwards and to the left on both surfaces. Further to the right these looped fibres are succeeded by circles which surround the organ completely. Traced towards the narrow end of the stomach, the circular bundles grow thicker, and at the pylorus they undergo a further increase, giving rise to the pyloric sphincter which surrounds the orifice as a thick muscular ring.

On the gastric side the pyloric sphincter passes gradually into the thick circular fibres of the pyloric portion of the stomach. On the opposite side it ceases abruptly, only its outer part being continued into the circular fibres of the duodenum (Fig. 681).

The *internal layer* (fibræ obliquæ) is composed of fibres which are arranged on the fundus and adjacent parts of the stomach, in much the same manner as those of the middle layer are on the body and pyloric portion of the organ (Fig. 680, C). Continuous above with the deeper circular fibres of the lower end of the œsophagus, they begin as U-shaped bundles which loop over the stomach immediately to the left of the cardia, and run very obliquely downwards and to the right for a considerable distance on both surfaces of the organ. These looped fibres, as we pass to the left, gradually become less oblique, and finally form circles which surround the wide end of the stomach completely, even as far as the summit of the fundus. The oblique fibres can be most readily shown by removing the circular fibres on either surface below the cardia. When traced towards the right, they will be found to terminate by turning down and joining the fibres of the circular layer.

The **submucous coat** (tela submucosa) is a layer of strong but loose connective tissue, which lies between, and unites, the muscular and mucous coats (Fig. 679). It is more loosely attached to the former and more closely to the latter coat, and it forms a bed in which the vessels and nerves break up before entering the mucous membrane.

The **mucous coat** (tunica mucosa), if examined in the fresh state soon after death, is of a reddish gray colour and of moderate consistence. When examined some time after death, the colour turns to a darker gray, and the whole membrane becomes softer and more pulpy. It is thicker (over 2 mm.) and firmer in the pyloric than in the cardiac portion, and is thinnest at the fundus, where it often shows signs of post-mortem digestion. When the stomach is empty all three outer coats, which are extensile, contract, whilst the inextensile mucous coat, as a result of its want of elasticity, is thrown into numerous prominent folds or *rugæ*, which project into the interior and, as it were, occupy the cavity of the contracted organ. These are, in general, longitudinal in direction, with numerous cross branches, and they are largest and most numerous along the great curvature. They disappear when the stomach is distended.

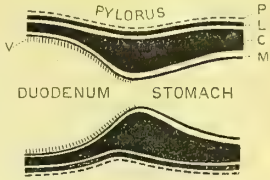


Fig. 681.—Diagram to show Formation of Pylorus. P, Peritoneum; L, Longitudinal layer of muscular fibres; C, Circular layer; M, Mucous membrane; V, Villi. It will be seen that the pyloric narrowing is due practically entirely to a gradual thickening of the circular muscular fibres, which stops abruptly at the pyloric orifice.

When the surface of the mucous coat is examined in a *fresh* stomach, it is seen to be marked out into a number of small, slightly elevated, polygonal areas (areæ gastricæ) by numerous linear depressions; the mucous membrane is consequently said to be *mammillated* (Fig. 682, A). These little areas, which measure from 1 to 6 mm. in diameter, are beset with numerous small pits (foveolæ gastricæ, about ·2 mm. wide), which are the mouths of the gastric glands, and they are so closely placed that the amount of surface separating them is reduced (particularly in the pyloric portion, where the gland mouths are widest) to a series of elevated ridges (plicæ villosæ) resembling villi on section. Although the gland mouths cannot be seen with the naked eye, a very slight magnification is sufficient to show them clearly; it is also possible to see the gland tubes leading off from the bottom of each (Fig. 682, B).

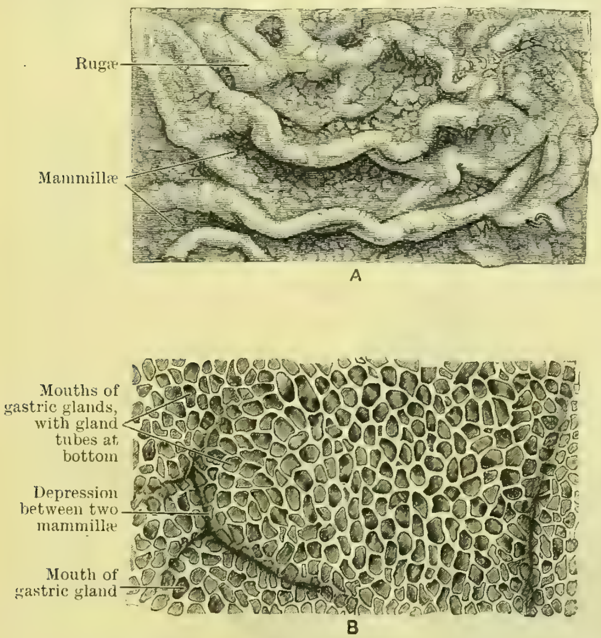


Fig. 682.—The Mucous Membrane of Stomach. A, Natural size; B, Magnified 25 diameters. In A the rugæ and the mammillated surface are shown. In B the gland mouths (foveolæ gastricæ), with the gland tubes leading off from some of them, and the ridges separating the mouths (plicæ villosæ) are seen.

Blood-vessels.—The **arteries** of the stomach are all derived ultimately from the cœliac axis. The *coronary* arises from this trunk direct. Having reached the lesser curvature and given off an œsophageal branch, it divides into two large branches, which run, one on each side, along this curvature, and join below with two similarly disposed arteries derived from the *pyloric* branch of the hepatic. From the two arches thus formed, four or five large branches pass to each surface of the stomach, and soon pierce the muscular coat. Along the great curvature several smaller branches reach the stomach from the *right and left gastro-epiploic arteries*, which are branches respectively of the gastro-duodenal and the splenic, and run in the great omentum close to its attachment to the stomach. Finally, four or five *vasa brevia*, branches of the splenic, are distributed to the fundus of the stomach, which they reach by passing forwards between the layers of the gastro-splenic omentum. At first the arteries lie beneath the peritoneum; very soon, however, they pierce the muscular coat, which they supply, and reaching the submucosa, break up to form a close network of vessels. From these arise numerous small

branches, which enter the mucous membrane and form capillary plexuses around the glands as far as the surface.

The **veins** begin in the capillary plexuses around the glands; uniting, they form a network in the submucosa, from which arise branches that pierce the muscular coat, and finally end in the following veins: the *right gastro-epiploic*, which joins the superior mesenteric; the *left gastro-epiploic*, and four or five veins corresponding to the *vasa brevia arteries*, which join the splenic; the *coronary* or *gastric vein*, which runs along the lesser curvature towards the cardia, receives an œsophageal branch, and then turns down and runs beside the coronary artery to join the portal trunk; and the *pyloric vein*, corresponding to the same named artery, which also joins the portal. These veins contain numerous valves, which, though competent to prevent the return of blood in the child, are rarely so in the adult.

The **lymphatics** arise in the mucous membrane around the gastric glands; they then join a plexus of valved vessels in the submucosa, from which the chief trunks pass with the blood-vessels to the curvatures, being joined on the way by the efferent vessels of a subperitoneal lymphatic plexus. They are connected with the superior gastric glands along the lesser curvatures, the inferior gastric glands along the great curvature, and the splenic glands, which they reach with the vasa brevia. Finally, the efferent vessels of all these join the cœliac glands.

The **nerves** are derived from the two *pneumogastrics* and from the *solar plexus* of the sympathetic. The pneumogastric nerves pass down through the diaphragm with the œsophagus, the left lying on its front, the right on its back; in this way they reach the upper and lower surfaces of the stomach respectively. Here they unite with the sympathetic fibres from the cœliac plexus (an offshoot of the solar plexus), which pass to the stomach with the branches of the cœliac axis. The nerve fibres, which are chiefly non-medullated, form two gangliated plexuses, those of Auerbach and Meissner, in the muscular and submucous coats respectively.

The development of the stomach is described with that of the intestines on page 1055.

INTESTINES.

As the coats of the remaining portions of the digestive tube agree in many particulars, it will be convenient to describe the general structure of the intestines here. Subsequently, any peculiarities of structure in particular regions will be described with the corresponding division of the tube.

Structure of the Intestines.

The wall of the intestines, like that of the stomach, is made up of four coats, which are named from without inwards—serous or peritoneal, muscular, submucous, and mucous (Figs. 683 and 684).

1. **Serous Coat** (tunica serosa).—This is formed of peritoneum, and confers on the

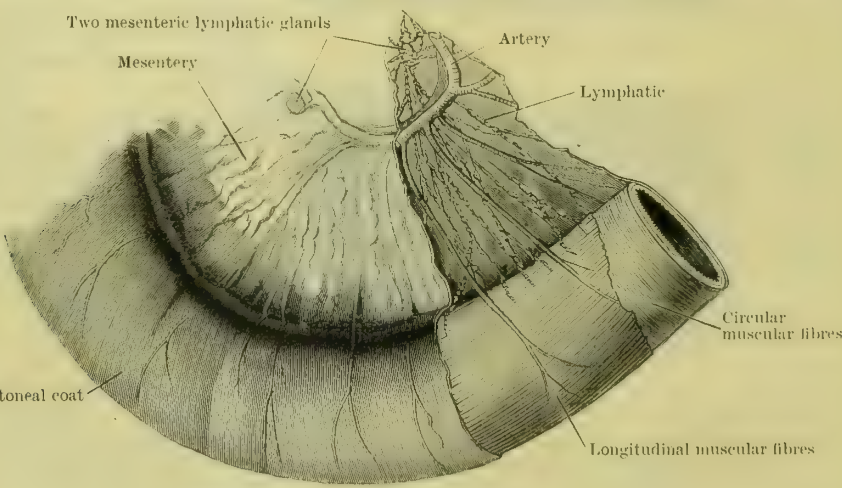


Fig. 683.—A Portion of Small Intestine, with Mesentery and Vessels. The peritoneal coat has been removed from the right half, and the two layers of the muscular coat exposed.

intestines their smooth and glossy appearance. It varies in the extent to which it clothes the different divisions of the tube, giving the duodenum, the ascending, descending, and iliac colons, and the rectum only a partial covering; whilst it clothes the jejunum and ileum, the cæcum, the transverse and the pelvic colons completely. The detailed

arrangement of this coat will be given with the description of each division of the intestinal tube.

2. **Muscular Coat** (tunica muscularis).—This consists of unstriped muscle arranged in two layers—an outer, in which the fibres run longitudinally, and an inner, in which they are circularly disposed. The muscular coat is thicker in the duodenum than in any other part of the small intestine, and it gradually diminishes in thickness until the end of the ileum is reached. On the other hand, in the large intestine, it is thickest in the rectum and thinner towards the beginning of the colon.

The **longitudinal layer** (stratum longitudinale) of this coat is much thinner than the underlying circular layer. In the small intestines it forms a complete sheet, continuous all round the gut (Fig. 683), but thickest at its free margin; whilst in the large intestine it is divided up into three longitudinal bands (Fig. 692), known as the *tæniæ coli*, which will be more fully described in connection with the colon.

The **circular layer** (stratum circulare), much thicker than the longitudinal layer, is composed of bundles of muscular fibres arranged circularly round the tube (Fig. 683), and forming in all parts a continuous sheet. Unlike the longitudinal fibres, those of the circular layer take part in the formation of the pyloric and ileo-cæcal valves.

3. **Submucous Coat** (tela submucosa).—This is a loose but strong layer of areolar tissue connecting the muscular and mucous coats, on which chiefly depends the strength of the intestinal wall. In addition to forming a bed in which the vessels break up before entering the mucous coat, it contains the glands of Brunner in the duodenum (Fig. 684), and in both small and large intestine the bases of the solitary glands lie in it (Fig. 684).

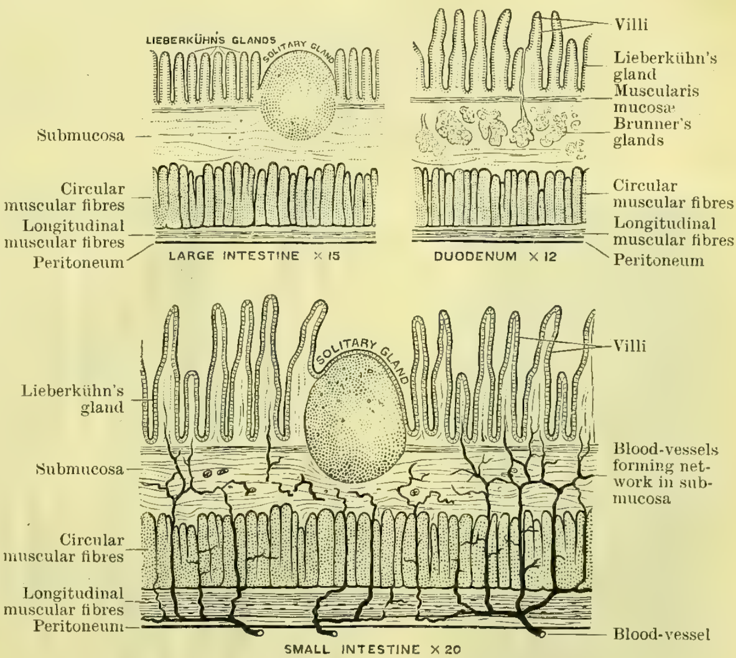


Fig. 684.—Diagram to show the structure of the small and large intestine and the duodenum.

4. **Mucous Coat** (tunica mucosa).—The mucous membrane constitutes the inner coat of the intestine, on which its digestive functions depend. It is everywhere composed (Fig. 684) of the following parts:—(1) A layer of striated, columnar, epithelial cells, resting on (2) a basement membrane. Outside this lies (3) a layer of retiform tissue, containing a considerable number of scattered lymphoid cells. This layer is limited towards the submucosa by (4) an extremely thin sheet of unstriped muscle, the **muscularis mucosa**, which is not visible to the naked eye. The mucous membrane is extremely vascular, particularly in the small intestine. It is thicker in the duodenum than in the jejunum, and thicker in this latter than in the ileum.

Throughout both the small and large intestines the substance of the mucous membrane is closely beset with innumerable small (microscopic) tubular glands, known as the **glands** or **follicles of Lieberkühn** (glandulæ intestinales). In shape they are minute straight tubes—like diminutive test-tubes—with their mouths opening on the surface, their closed ends lying in the deeper part of the mucous coat, and their cavities lined by columnar epithelium. They open on the surface between the villi of the small intestine, and are present also on the valvulæ conniventes. In the large gut their orifices are found all over the surface of the mucous membrane.

Certain special developments of the mucous coat, found in particular regions of

the intestinal tube, must next be considered: these are the (1) villi; (2) valvulæ conniventes; (3) solitary glands; and (4) agminated glands, or Peyer's patches.

Villi (villi intestinales).—If the mucous membrane of any part of the small intestine be examined, it is seen to present a soft, velvety, or fleecy appearance (Fig. 685, B); this is due to the presence of an enormous number of minute processes, known as villi, which cover its surface.

Villi are minute cylindrical or finger-like projections of the mucous membrane (Fig. 684), about $\frac{1}{30}$th or $\frac{1}{40}$th of an inch (1·2 to 1·6 mm.) in height, and barely visible to the naked eye, which are closely set all over the surface of the mucous membrane of the small intestine. Beginning at the edge of the pyloric valve, they are said to be broader but shorter in the duodenum, and to grow narrower as they are followed down through the intestine to the ileo-cæcal valve, at the edge of which they cease. They are found, not only on the general surface of the mucous membrane, but also upon the valvulæ conniventes, and, while they are not present over the solitary glands, they are found in the intervals between the individual nodules of the Peyer's patches.

They are connected with the absorption of the products of digestion which takes place in the small intestine.

Valvulæ Conniventes (plicæ circulares).—When the intestine is empty and contracted, its mucous membrane may in places be thrown into effaceable folds or rugæ, which disappear on distention. But in addition to these, there are found in certain portions of the small intestine a series of large, permanent folds, which are not effaceable; these are known as valvulæ conniventes (Fig. 685). They are usually more or less crescentic in shape, and resemble a series of closely-placed shelves running transversely around the gut. They rarely form more than two-thirds of a circle; sometimes, however, they present a circular or even a spiral arrangement, the spiral extending little more than once round the tube, as a rule. Occasionally they bifurcate at one or both ends; sometimes, too, short irregularly directed branches pass off from them. They are usually about 2 to 3 inches (5 to 7·5 cm.) in length, and their breadth, that is their projection into the cavity, may be as much as $\frac{1}{3}$rd of an inch (8 mm.), whilst in thickness, as seen when cut across, they measure about $\frac{1}{8}$th inch (3 mm.)

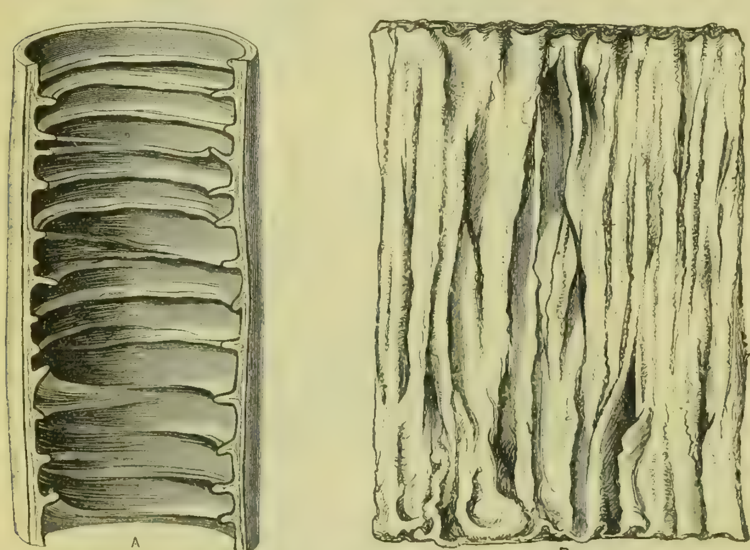


Fig. 685.—Valvulæ Conniventes (natural size).
A, as seen in a bit of jejunum which has been filled with alcohol and hardened; B, a portion of fresh intestine spread out under water.

They are composed of two layers of mucous membrane, placed back to back, with a little submucosa between, to bind the two together, and are covered with villi and Lieberkühn's glands. Their use is to increase the amount of surface available for secretion and absorption.

Valvulæ conniventes are not found in the upper part of the duodenum for a distance varying from 1 to 2 inches (2·5 to 5 cm.) from the pylorus. Here they begin, and are at first small, irregular, and scattered; but they grow gradually larger as we pass down, and when the opening of the bile-duct is reached

(4 inches from the pylorus) they have become distinct and prominent. In the rest of the duodenum, and in the upper half of the jejunum, they are highly developed, being large, broad, and closely set. In the lower half of the jejunum they become gradually smaller and fewer. Passing down into the ileum, they become still smaller and more irregular, and, as a rule, they practically cease a little below the middle of the ileum.

The mucous membrane covering the folds possesses villi, solitary glands, and Lieberkühn's glands, like the mucous membrane of the general surface between the valves.

' Often patches of valvulæ conniventes, much reduced in size, can be traced to within a short distance of the ileo-cæcal valve. According to Sappey, Luschka, and others, they usually reach to within two or three feet of the end of the ileum.

They are said to be absent in mammals, with the exception of man and the ornithorhynchus.

Solitary Glands (noduli lymphatici solitarii).—These are minute nodules of lymphoid tissue, opaque and of a whitish colour, found projecting on the surface of the mucous membrane throughout the whole length of both the small and large intestines.

Isolated lymphoid cells are found in abundance scattered through the connective tissue layer of the intestinal mucous membrane generally; in places these cells are gathered together to form little nodules, supported by a framework of retiform tissue, and surrounded by a lymphatic space which communicates below with the lymphatics of the submucosa. Such a collection of lymphoid cells constitutes a solitary gland. They are usually of a rounded or oval shape (Fig. 684), the wide end resting in the submucosa, the nodule itself piercing the muscularis mucosæ, and the narrow end projecting slightly above the surface of the mucous membrane. In size they vary from $\frac{1}{40}$th to $\frac{1}{8}$th of an inch (·6 to 3·0 mm.), but their average bulk is about that of a small grain of sago, to which they bear some resemblance.

As already mentioned, they are present throughout the small and large intestines, being particularly abundant in the vermiform appendix and cæcum. In the small intestine they are found on the valvulæ conniventes, as well as upon the general surface of the mucous membrane between them.

FIG. 686.—PEYER'S PATCH AND SOLITARY GLANDS, from intestine of child two years old (natural size).

Near the lower border are seen a few small patches made up of two or three lymphatic nodules; they are marked "intermediate form."

Peyer's Patches, or Agminated Glands (noduli lymphatici aggregati, tonsillæ intestinales).—A Peyer's patch consists of a large number of lymphoid nodules grouped closely together so as to form a slightly elevated area, usually of an oblong form, on the surface of the mucous membrane (Fig. 686). In length they vary from half an inch (12 mm.) or less to three or four inches (100 mm.), and in width they commonly measure from a third to half an inch (8 to 12 mm.). Their number is variable, but in the average condition about 30 or 40 are found. They are best marked in young subjects, where they form considerable elevations above the general surface, and may be as many as 45 in number. After middle life they atrophy, and in old age, although usually to be found, they are indistinct, occasionally being marked by little more than a dark discoloration of the mucous membrane. They are invariably situated along the free surface of the intestine opposite the line of mesenteric attachment, with their long axis corresponding to that of the bowel. Consequently, in order to display them, the tube must be slit up along its attached or mesenteric border.

Peyer's patches are entirely confined to the small intestine, being largest and

most numerous in the ileum, particularly in its lower part, where they usually assume an oblong shape; in the lower half of the jejunum they are small, circular, and few in number; in its upper part they are rare; and, although their presence has been noted in the lower portion of the duodenum, they may be said to be as a general rule absent from this division of the intestine.

The valvulæ conniventes stop at the margins of Peyer's patches, and are not continued across them; but villi are found on the surface of the patches, in the intervals between the lymphoid nodules.

The chief bowel lesion in typhoid fever is found in Peyer's patches and the solitary glands.

When the surface of a Peyer's patch from a child's intestine (in which these structures are particularly well developed) is carefully examined, it is seen to be made up, not of a series of separate, rounded nodules grouped together, but rather of a number of wavy, irregular, and branching ridges connected with one another by cross branches (Fig. 686), the whole recalling in miniature, the appearance of a raised map of a very mountainous district in which the chief chains run irregular courses, and are joined to one another by connecting ridges.

Small patches, intermediate in form between solitary glands and Peyer's patches, and consisting of two or three lymphoid nodules, are also usually present.

THE SMALL INTESTINE.

The **small intestine** is the portion of the digestive tube which is placed between the stomach and the beginning of the large intestine. It commences at the pylorus, where it is continuous with the stomach, and ends at the ileo-cæcal valve by joining the large intestine. It occupies the greater portion of the abdominal cavity below the liver and stomach (Fig. 671), and is found in the umbilical, hypogastric, and both lumbar regions; also, but to a less extent, in the other regions of the abdomen, and in the pelvic cavity.

In *length*, the small intestine usually measures over 20 feet. According to Treves, it is 22½ ft. in the male, 23 in the female, whilst Jonnesco gives the average length at 24 ft. 7 ins., or 7½ metres. In form it is cylindrical, with a *diameter* varying from nearly two inches (47 mm.) in the duodenum to a little over an inch (27 mm.) at the end of the ileum; there is thus a gradual diminution in its size from the pylorus to the ileo-cæcal valve.

This portion of the digestive tube is divided more or less arbitrarily into three parts (Fig. 636)—namely, the **duodenum**, constituting the first eleven inches, distinctly marked off from the rest by its fixation and the absence of a mesentery; the **jejunum**, which comprises the upper two-fifths, and the **ileum**, the lower three-fifths of the remainder. The two latter parts pass imperceptibly into one another, and the line of division drawn between them is entirely artificial; however, if typical parts of the two—namely, the beginning of the jejunum and the end of the ileum—be selected, they differ so much in size and in the appearance presented by their lining mucous membrane, that they can be distinguished from one another without difficulty.

Both the jejunum and ileum are irregularly disposed in the form of crowded loops or coils (Fig. 670) which are connected to the posterior abdominal wall by a great fan-shaped fold of peritoneum, containing their vessels and nerves, and known as the **mesentery**. This is of such a length that the coils are able to move about freely in the abdominal cavity, and consequently the position occupied by any portion of the tube, with the exception of the beginning of the jejunum and the ending of the ileum, can never be stated with certainty. Nevertheless, it may be said that, in general, the jejunum occupies the upper and left portions of the cavity below the stomach, the ileum the lower and right divisions, its terminal part almost always lying in the pelvis, just before it joins the large gut.

The small intestine is relatively longer in the child than in the adult; at birth it is to the total height of the child as 7 to 1, whilst in the adult the proportion is as 4 to 1. Notwithstanding Treves' results, it is generally held that the small gut is relatively longer in the male than the female.

It should perhaps be added that in formalin-hardened bodies the small bowel rarely measures more than 12 or 13 feet in length. Similarly its diameter is often reduced in places to ½ or ¾ inch (12·5 to 18·7 mm.), although the greater part of the gut may retain its usual width: these narrow parts have apparently been fixed in a state of contraction.

THE DUODENUM.

The **duodenum**, the portion of the digestive tube which immediately succeeds the stomach, is the first part of the small intestine, and differs from the rest of that tube in having no mesentery, and also in being closely fixed to the posterior abdominal wall—conditions which are evidently associated with its relation to the bile and pancreatic ducts, both of which open into its cavity.

Shape and Divisions.—The duodenum begins at the pylorus, about the level of the first lumbar vertebra, and ends, after a somewhat C-shaped course, at the left side of the first or second lumbar vertebra (Fig. 687). It is generally described as being made up of three parts, namely:—(1) The **first** or **superior portion** which begins at the pylorus, passes backwards and to the right beneath the liver, and ends at the neck of the gall-bladder, by turning down and joining (2) the **second** or **descending portion**. This begins at the neck of the gall-bladder, runs down behind the transverse colon (Fig. 688), and ends opposite the third or fourth lumbar vertebra by turning to the left, and passing into (3) the **third** or **inferior portion**. This at first runs more or less transversely to the left, across the vena cava, and then ascends, in front of the aorta, as far as the under surface of the pancreas, where, at the level of the first or second lumbar vertebra, it bends abruptly forwards, forming the **duodeno-jejunal flexure** (Fig. 687), and passes into the jejunum.

Taking the whole of the duodenum together, it forms an irregularly C-shaped curve, with the opening of the C directed upwards and to the left, and the ends reaching to within about two inches of one another. Within the concavity of the curve the head of the pancreas is placed.

The incomplete ring which the duodenum makes does not all lie in the same plane; for, whilst its greater part is placed in a transverse-vertical plane, the middle portion bends strongly backwards, round the right side of the vena cava, and lies almost in a sagittal plane (Fig. 687).

Position and Size.—As a rule, a little more than half of the duodenum lies in the epigastrium, the remainder, namely, about the lower third of the descending portion and the adjoining two-thirds of the inferior or third portion, are placed in the umbilical region. With the exception of the terminal ascending portion of the third part, the whole of the duodenum lies to the right of the middle line.

Its length is usually about 11 inches (27·5 cm.), its first portion being the shortest and its third portion the longest. Its diameter varies considerably, and may be stated to average about 1½ inches when empty, but it may be as much as two inches when distended.

Relations.—The **first** or **superior portion** (pars superior) begins at the pylorus opposite the first lumbar vertebra. From this it runs to the right, and then backwards, beneath the liver, when the stomach is empty; but directly backwards when it is full; and ends at the neck of the gall-bladder by turning downwards and passing into the second part. Its length varies from about 1½ to 2 inches (3·7 to 5·0 cm.), and is said to be greater when the stomach is empty than when distended.

Its relations (Figs. 687 and 688) are as follows:—*Above and in front* lies the quadrate lobe of the liver, which hangs downwards and to the right over the tube. *Below*, it rests on the head and neck of the pancreas (the latter running up behind it for a little way). *Behind it*, close to the pylorus, the portal vein ascends to the liver, and the bile duct with the gastro-duodenal artery passes downwards. Further to the right, as it bends backwards, it lies against the right side of the vena cava.

Its *peritoneal relations* for about an inch from the pylorus are the same as those of the pyloric end of the stomach, that is to say, both the anterior and posterior surfaces are covered, and the lesser and great omenta are attached to its upper and lower borders respectively (Fig. 688). Beyond this, however, only the anterior surface has a serous coat.

The peritoneal covering of the first half of the posterior surface is derived from a diverticulum of the small sac which runs to the right behind the duodenum for the distance mentioned.

When the stomach is distended, the first inch of the duodenum—which is movable on account of its complete peritoneal covering—is carried to the right with the pylorus, and thus brought into line with the second or terminal half, which is always directed backwards. Hence the whole of the first portion of the duodenum is directed backwards when the stomach is full.

The **second** or **descending portion** (pars descendens) begins at the neck of the gall-

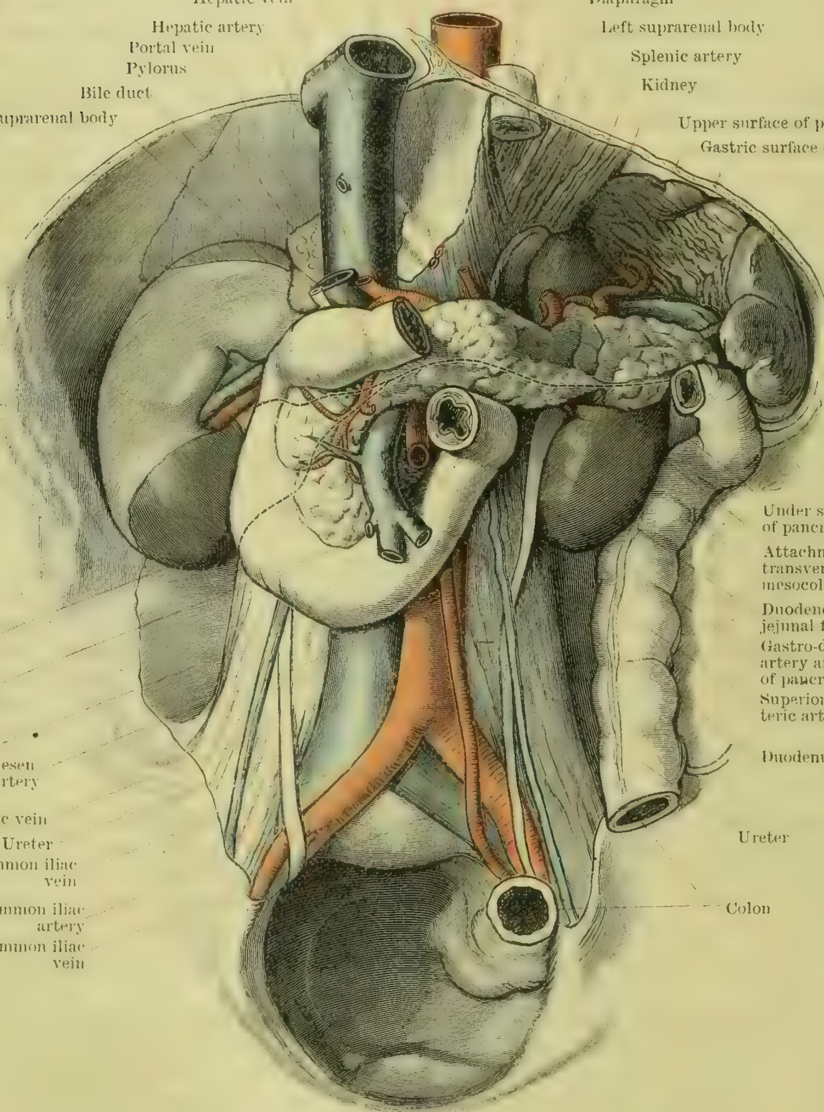


FIG. 687.—THE VISCERA AND VESSELS ON THE POSTERIOR ABDOMINAL WALL.

The stomach, liver, and most of the intestines have been removed. The peritoneum has been preserved on the right kidney, and the fossa for the Spigelian lobe. In taking out the liver, the vena cava was left behind. The stomach-bed is well shown. (From a body hardened by injection of chromic acid.)

bladder, passes down behind the transverse colon, and ends at the right side of the third or fourth lumbar vertebra. In length it measures $3\frac{1}{2}$ or 4 inches (8·7 to 10 cm.).

In front, it is crossed about its middle by the beginning of the transverse colon (Fig. 688). Above the colon, it is in contact with the narrow end of the gall-bladder

and below it with the coils of the small intestine. *Behind*, it is connected by areolar tissue to the inner part of the right kidney, with its ureter and renal vessels; it is also related, as a rule, to the right psoas muscle below the kidney (Fig. 687). To its *outer or right side* lies the liver (here presenting the duodenal impression) above, and often the ascending colon below. To its *inner side* are the inferior vena cava and the head of the pancreas, this latter overlapping it somewhat in front.

The common bile duct, after passing down behind the first portion of the duodenum, descends between the head of the pancreas and the second portion, nearly as far as its middle; here it is joined by the pancreatic duct, and the two,

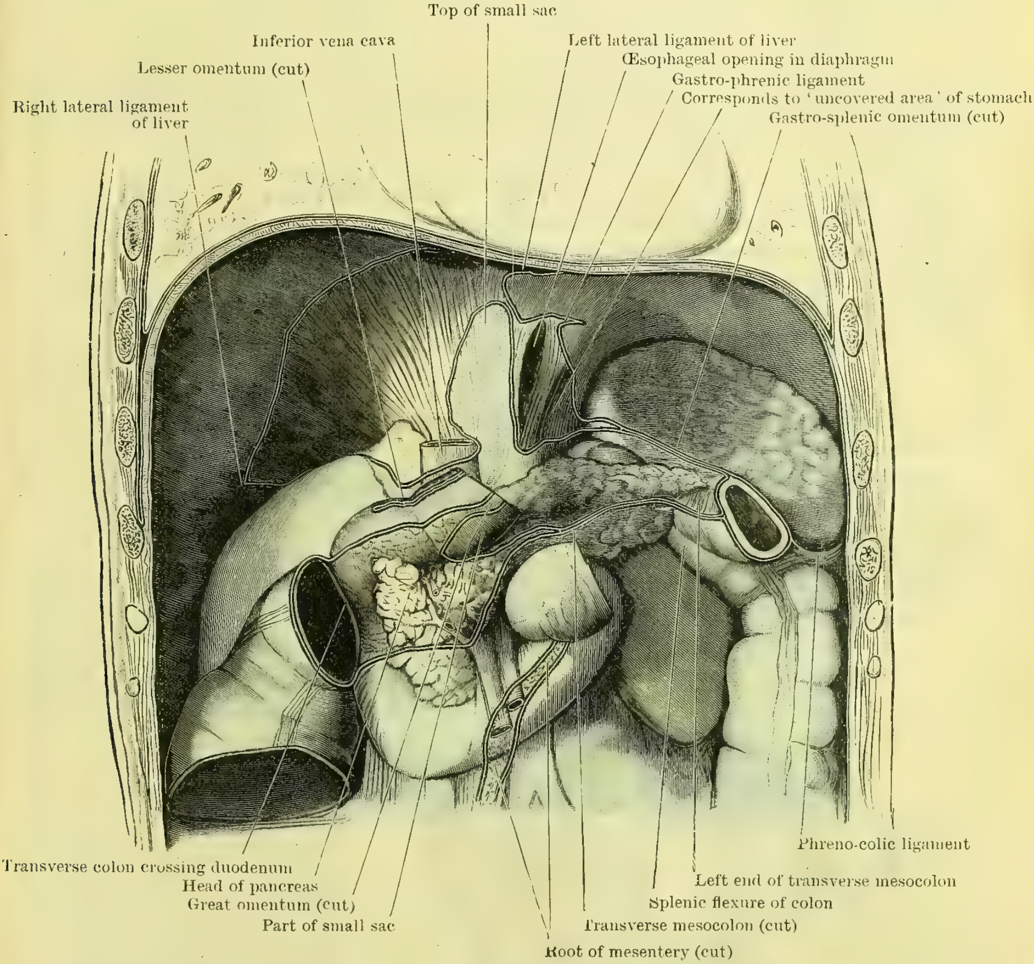


FIG. 688.—THE PERITONEAL RELATIONS OF THE DUODENUM, PANCREAS, SPLEEN, KIDNEYS, ETC.

From a body hardened by injections of formalin. In removing the liver, stomach, and intestines the lines of the peritoneal reflexions were carefully preserved. The peritoneum is coloured blue.

piercing the wall of the duodenum obliquely, open by a common orifice on its inner aspect, about $3\frac{1}{2}$ to 4 inches (8·7 to 10 cm.) beyond the pylorus.

Peritoneal relations.—There is no peritoneum on the posterior or deep surface of this part, whilst its superficial or anterior surface is covered, except where it is crossed by the colon (Fig. 688).

When the beginning of the transverse colon is completely covered by peritoneum, and has a mesentery (a condition which often seems to be determined by a liver large in the vertical direction), the whole of the anterior surface, with the exception of the insignificant area between the two layers of the transverse mesocolon, is covered by the peritoneum.

On the other hand, when this part of the colon has no mesentery, it lifts the peritoneum off the front of the duodenum, and leaves a considerable "uncovered area," which is united by areolar tissue to the back of the colon.

The **third or inferior portion** (pars inferior) begins at the right side of the third or fourth lumbar vertebra. From this it first runs more or less transversely to the left across the vena cava (Fig. 687) for one or two inches, and then passes very obliquely, or even vertically, upwards in front of the aorta and left psoas muscle. Finally, having reached the lower surface of the pancreas, it bends forwards, and passes into the jejunum. Owing to the different directions which they take, we can recognise two divisions, a transverse and an ascending terminal, in this portion of the duodenum (Fig. 687).

In front, it is crossed (about the junction of its two divisions) by the superior mesenteric vessels, and also by the root of the mesentery (Fig. 688). On each side of this it is covered by coils of small intestine. *Behind*, its horizontal portion lies on the vena cava; its ascending portion on the aorta, the left renal vessels, and the left psoas muscle, all of which separate it from the vertebral column. *Above*, it is closely applied in its whole extent to the head of the pancreas. The *left side* of the *ascending terminal part*, which is free, lies in contact with some coils of the small intestine.

Peritoneal relations.—The third portion of the duodenum is covered by peritoneum on its anterior surface throughout, except where it is crossed by the superior mesenteric vessels and the root of the mesentery which contains them (Fig. 688). In addition, its ascending terminal portion is also clothed by this membrane on its left side; and here are usually found one or two small peritoneal pouches known as the **duodenal fossæ**.

The attachment of the root of the mesentery begins above quite close to the duodeno-jejunal flexure, on the front of the duodenum; from this it runs down on the anterior aspect of the ascending terminal part, and finally leaves the duodenum about the union of the two divisions of its third portion.

Duodenal Fossæ.—In the neighbourhood of the ascending part of the third portion of the duodenum are found three well-known fossæ of the peritoneum which are of some surgical interest; these are the superior and inferior duodenal and the paraduodenal fossæ (Fig. 689). Other rarer forms are occasionally present.

When the ascending terminal part of the duodenum is drawn over to the right, and the angle between its left side and the posterior abdominal wall examined, one or two triangular folds of peritoneum will generally be found crossing over this angle from the duodenum to the abdominal wall. Each fold has one edge attached to the duodenum, another to the parietal peritoneum at the left of. the duodenum, whilst the third is free, and bounds the opening of a small pouch which lies behind the fold. One of these, the *superior duodenal fold*, is situated near the termination of the duodenum, with its apex directed up and its free margin down. It sometimes contains between its two layers the termination of the inferior mesenteric vein. Behind it lies the **superior duodenal fossa**, the opening of which looks downwards, and will usually admit the tip of a finger (Fig. 689). The second, known as *the inferior duodenal fold*, is placed lower down, at the side of the same part of the duodenum. Its free border is directed upwards, as is the mouth of the **inferior duodenal fossa**, which lies behind it. This latter is larger and more constant than the superior duodenal fossa, and is present in 75 per cent of bodies, whilst the superior is present in 50 per cent (Jonnesco).

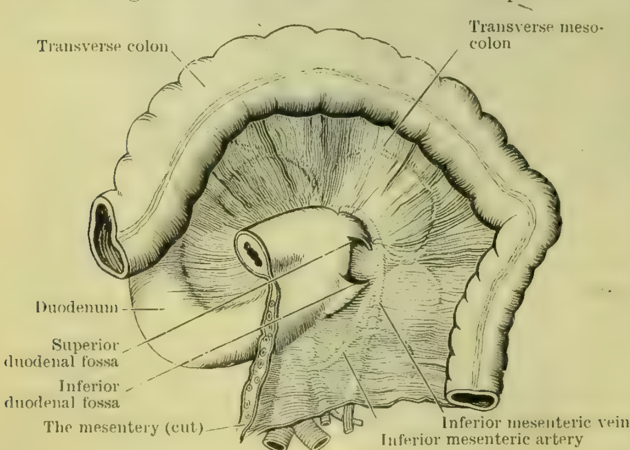


FIG. 689.—THE DUODENAL FOSSÆ AND FOLDS.

The transverse colon and mesocolon have been thrown up, and the mesentery has been turned to the right and cut. The paraduodenal fossa (of Landzert) is situated to the inner side of the inferior mesenteric vein, between it and the terminal part of the duodenum. It is not shown in the illustration.

Paraduodenal Fossa (fossa of Landzert).—This fossa, which is best seen in the infant, is placed some distance to the left of the terminal part of the duodenum. It is produced by the inferior mesenteric vein raising up a fold of peritoneum, as it runs along the outer side of the fossa, and then inwards above it (see Fig. 689, where the vein, but not the fossa, is shown). It is limited below by a special fold (the mesenterico-mesocolic fold). According to Moynihan, this is the only fossa to the left of the duodenum capable of developing into the sac of a hernia; and when this occurs, the inferior mesenteric vein always lies in the anterior margin of the orifice of the sac (accompanied for some distance by the ascending branch of the left colic artery).

In addition to the above, a duodeno-jejunal fossa at the front of the duodeno-jejunal flexure, and five other fossæ, have—perhaps unnecessarily—been described in this region.

Peritoneal Relations of the Duodenum.—Whilst the relations of the peritoneum to the second and third portions of the duodenum are usually described as in the foregoing account, it should perhaps be pointed out, that it is not really the front, but the right half of the circumference of the descending portion which has a serous coat. Similarly, it is the lower and anterior half of the circumference of the transverse part of the third portion which is clothed by peritoneum, whilst considerably more than half of the circumference of its ascending terminal part is covered; for the peritoneum forms a fold running in behind this part, in addition to covering its left side and half its anterior aspect.

Interior of Duodenum.—No valvulæ conniventes are found in the duodenum for an inch or two beyond the pylorus. Here they begin; at first as low, scattered, and irregular folds; further down, they gradually become larger, more regular, and more numerous; and by the time the middle of the descending stage is reached they have attained a considerable development. In the lower part of the duodenum the folds are large, prominent, and closely set.

On the inner aspect of the descending portion, about its middle—namely, 3½ or 4 inches (8·7 to 10 cm.) beyond the pylorus—is seen a prominent papilla, on which the bile and pancreatic ducts open by a common orifice (Fig. 690). This is known as the **bile papilla** (papilla duodeni; caruncula major of Santorini).

Fig. 690.—The Bile Papilla in the Interior of the Duodenum.

The bile papilla is placed beneath, and protected by, a prominent, hood-like valvula connivens, which is situated immediately above it. From its lower margin a firm ridge of the mucous membrane (the plica longitudinalis duodeni) descends for a considerable distance, and acts as a frenum, which fixes the papilla and directs its apex somewhat downwards (Fig. 690). The papilla is prominent, and nipple or dome-shaped, and at its summit is placed the small orifice, which will usually admit the point of a pencil; the whole bears a close resemblance to the nozzle of a perfume-spray.

Nearly an inch higher up, and invariably on the ventral side of the bile papilla (sometimes as much as a ½ to ¾ inch distant), is seen a second and smaller papilla (the caruncula minor of Santorini), at the point of which is placed the very small orifice of the accessory pancreatic duct. This second papilla seems to be constantly present, although sometimes so small that it may easily escape detection unless carefully sought for. When well developed, it may have a hood-like valvula connivens and a little frenulum, like those of the bile papilla.

Structure of the Duodenum.—The **peritoneal coat,** which is incomplete, has already been described in detail, in connection with each division of the duodenum.

The **muscular coat** is well developed, and is pierced by the bile and pancreatic ducts, but otherwise calls for no special description.

The **submucosa** differs from that of the rest of the small intestine, in that it contains, especially in the upper half of the duodenum, the **glands of Brunner** (glandulæ duodenales). These are small acinotubular glands, closely resembling the pyloric glands of the stomach, which lie in the submucous coat, and send their ducts through the muscularis mucosæ to open on the surface between Lieberkühn's glands, or sometimes into these glands themselves (Fig. 684). They can be exposed by removing the peritoneal and muscular coats, and also some of the submucosa, when they appear as little round or flattened masses of a reddish gray colour, varying in size from $\frac{1}{50}$th to $\frac{1}{12}$th of an inch in

diameter (·5 to 2·0 mm.). They form an almost continuous layer as far as the opening of the bile duct; beyond this they diminish progressively, and completely disappear near the duodeno-jejunal flexure.

The **mucous membrane**, which is thicker in the duodenum than in any other part of the small intestine, is covered throughout with broad short villi. Its other characteristics have been already fully described.

Various Forms of Duodenum.—Three different types of duodenum have been described—(1) The **annular**, in which the curves separating the various portions are open, and the two extremities come fairly close to one another. (2) The **U-shaped**, in which the transverse part of the third portion is very long, and the ascending portion nearly vertical; and (3) the **V-shaped** duodenum, in which the transverse part of the third portion is very short or absent.

Duodenal Pouch.—A diverticulum of the duodenum, arising from its left side just above the opening of the bile duct, and running into the substance of the pancreas, is occasionally found. It is possibly connected with one of the outgrowths of the duodenum from which the pancreas is developed in the embryo.

Vessels and Nerves.—The duodenum receives its blood from the superior and inferior pancreatico-duodenal arteries, branches of the gastro-duodenal and superior mesenteric arteries respectively. The blood is returned by the corresponding veins, the superior of which opens into the superior mesenteric, and the inferior into the beginning of the portal vein.

The **lymphatics** pass to a set of glands placed along the pancreatico-duodenal arteries, and thence to the cœliac glands.

The **nerves** come from the solar plexus of the sympathetic.

Duodeno-jejunal Flexure.—When the ascending terminal portion of the duodenum reaches the under surface of the pancreas, at a point opposite the left side of the first or second lumbar vertebra, it turns abruptly forwards, downwards, and to the left, and passes into the jejunum. This abrupt bend is known as the **duodeno-jejunal flexure.** Unlike the rest of the duodenum, which is subject to considerable variations in position, the duodeno-jejunal flexure is fixed by a thin band of unstriped muscle, which is attached above to the strong connective tissue around the cœliac axis, as well as to the left crus of the diaphragm, and below joins the muscular coat of the duodenum at the flexure. This band is known as the **suspensory muscle of the duodenum** (musculus suspensorius duodeni—Treitz).

The course taken by the gut at the duodeno-jejunal flexure is variable: the chief directions in their order of frequency are—(1) downwards, forwards, and to the left; (2) directly forwards and downwards; (3) to the left, and then downwards; (4) forwards and to the right (Harman).

Some of the fibres of the suspensory muscle are said by Lockwood to pass into the mesentery, and he consequently calls it "the suspensory muscle of the duodenum and mesentery proper."

THE JEJUNUM AND ILEUM.

The upper two-fifths, that is, about 8 feet of the small intestine beyond the duodenum, are known as the **jejunum** (intestinum jejunum). The succeeding three-fifths, which usually measures about 12 feet, constitute the **ileum.** The ileum opens into the large intestine at the junction of the cæcum and ascending colon, where its orifice is guarded by the ileo-cæcal valve.

Both the jejunum and ileum are connected to the parietes by a large fold of peritoneum—*the mesentery*—which conveys vessels and nerves from the posterior abdominal wall to these divisions of the intestine.

The part of the tube to which the mesentery is connected is known as the mesenteric or attached border, the opposite side is the free border.

The **mesentery** (mesenterium) is a broad fan-shaped fold, composed of two layers of peritoneum, which connects the small intestine to the back of the abdomen. One border of the fold is wide and contains the intestine within it (Fig. 683). The other, known as the *root of the mesentery* (radix mesenterii), is comparatively narrow, being only 6 or 7 inches wide, but it is much thicker than the part near the gut, for it contains between its layers a considerable amount of fatty subperitoneal tissue, in addition to the large vascular trunks passing to the intestine. The root is attached to the posterior abdominal wall along an oblique line, extending approximately from the left side of the second lumbar vertebra to the right iliac fossa (Fig. 691). In this course its line of attachment passes from the duodeno-jejunal flexure down the front of

the terminal part of the duodenum, then obliquely across the aorta, the inferior vena cava, the ureter, and psoas muscle, to reach the right iliac region.

The opposite border of the mesentery is frilled out to an enormous degree, so that, while the root measures but 6 or 7 inches, the free border is extended to some 20 feet, thus resembling a fan, one border of which may be twenty or thirty times as long as the other. The length of the mesentery, measured from its root to the attached edge of the intestine directly opposite, usually measures at its longest part about 6 inches (8 or 9 inches, Treves and Lockwood).

Between the two layers of the mesentery (Fig. 683) are contained (*a*) the intestinal branches of the superior mesenteric vessels, accompanied by the mesenteric nerves and lymphatics; (*b*) the mesenteric lymphatic glands, which vary from 40

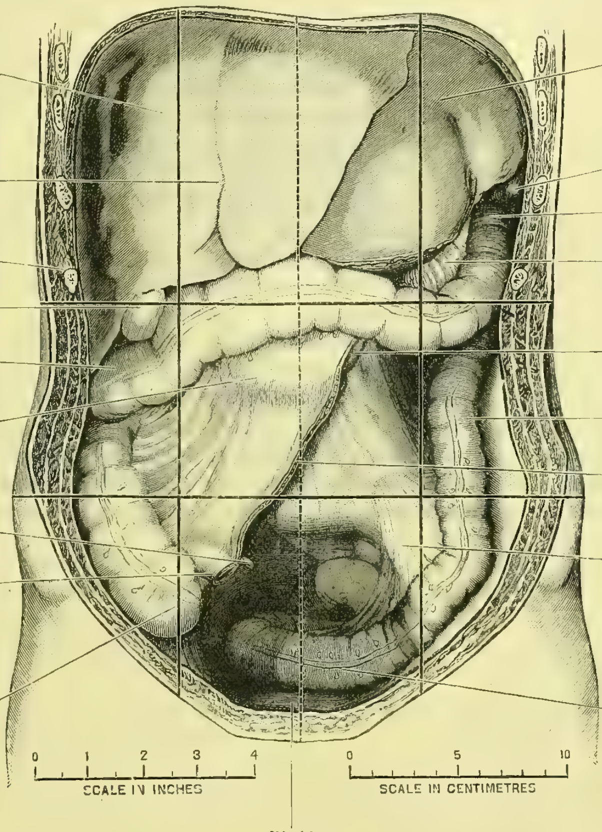


FIG. 691.—THE ABDOMINAL VISCERA AFTER THE REMOVAL OF THE JEJUNUM AND ILEUM (from a photograph of the same body as depicted in Fig. 670). The transverse colon is much more regular than usual. Both the liver and cæcum extend lower down than normal. The subdivisions of the abdominal cavity are indicated by dark lines.

to 150 in number; (*c*) a considerable amount of fatty connective tissue, continuous with the extra-peritoneal areolar tissue; and (*d*) the intestine itself.

The peritoneum from the right side of the mesentery passes out on the posterior abdominal wall to clothe the ascending colon, and above, it is connected by a fold with the transverse mesocolon. That of the left side, similarly, passes across the parietes to the descending and iliac colons.

The mesentery begins above, immediately beyond the ending of the duodenum—that is, in the angle of the duodeno-jejunal flexure—and it ends below in the angle between the ileum and ascending colon. It is very short at each end, but soon attains the average length. Its longest part goes to the portion of the small intestine situated between two points, one six feet, the other eleven feet from the duodenum (Treves).

Whilst the root of the mesentery pursues at its attachment an almost straight line from one end to the other, if cut across a very short distance from the posterior abdominal wall, it will here be found to form a wavy or undulating line. Further out still this condition becomes more and more marked; and finally, if the bowel be removed by cutting through the mesentery close to its attach-

ment to the intestinal wall, it will be seen that its free edge is not only undulating, but is frilled or plaited to an extreme degree. When shown in this way, it is found that the plaiting or folding is not quite indiscriminate, but that the main folds, of which there are usually six, run alternately to the right and left. As a rule, the first fold runs to the left from the duodeno-jejunal flexure, and goes to a coil of jejunum which lies under the transverse mesocolon, and helps to support the stomach (this coil has been already referred to, page 1003). The second fold passes to the right, the third to the left, and so on up to the fifth and sixth, which are usually small. From the margins of these primary folds secondary folds project in all directions, and from these again even a third series may be formed.

This order is of course by no means constant, but if the intestine be removed from a hardened body in the way suggested, without disturbing the mesentery, it will be found to be arranged with more or less regularity on some such plan as that indicated.

Arrangement of Coils of Small Intestine.—Although the greatest variety is found in the disposition of the small intestine, and it is impossible to state in what regions of the abdomen the different parts of the tube will be found, still it may be said that in general the jejunum (as might be expected from the position at which it begins) is placed above and to the left, in reference to the ileum, which latter lies below and to the right. Again, the upper part of the jejunum is usually situated to the left of the duodeno-jejunal flexure, in contact with the under surface of the pancreas and transverse mesocolon; and, similarly, the terminal part of the ileum almost always lies in the pelvis, from which it passes up over the right side of the pelvic brim to reach the ileo-cæcal orifice. Another portion of the small intestine is not uncommonly found in the pelvis; this is the part with the longest mesentery, and lies between two points, six and eleven feet respectively from the duodenum (Treves).

Differences between Jejunum and Ileum.—If the small intestine be followed down from the duodenum to the cæcum no noticeable change in appearance will be found at any one part of its course, to indicate the transition from jejunum to ileum; for the one passes insensibly into the other. Nevertheless, a gradual change takes place, and if typical parts of the two, namely, the upper portion of the jejunum and the lower portion of the ileum, be examined, they will be found to present characteristic differences, which are set forth in the following table:—

Jejunum.	Ileum.
Wider, $1\frac{1}{2}$ to $1\frac{1}{4}$ inch in diameter.	Narrower, $1\frac{1}{4}$ to 1 inch in diameter.
Wall, thicker and heavier.	Wall, thinner and lighter.
Redder and more vascular.	Paler and less vascular.
Valvulæ conniventes well developed.	Valvulæ conniventes absent or very small.
Peyer's patches, few and small.	Peyer's patches, large and numerous.

The villi are also said to be shorter and broader in the jejunum, more slender and filiform in the ileum (Rauber).

The terminal portion of the ileum, after crossing the brim of the pelvis, runs upwards, and also slightly backwards and to the right, in close contact with the cæcum, until the ileo-cæcal orifice is reached.

Meckel's Diverticulum (diverticulum ilei).—This is a short wide protrusion which is found springing from the lower part of the ileum in a little over 2 per cent of the bodies examined. It is usually about 2 inches long, and of the same width as the intestine from which it comes off. Most commonly it is found about $2\frac{3}{4}$ feet from the ileo-cæcal valve, and opposite the termination of the superior mesenteric artery. As a rule, it runs at right angles to the gut, and its end is free; but occasionally it is adherent either to the abdominal wall, the adjacent viscera, or the mesentery, when it may be the cause of strangulation of the intestine.

The diverticulum is due to the persistence of the proximal portion of the vitelline (or vitello-intestinal) duct, which connects the primitive intestine of the embryo with the yolk sac. In shape it may be cylindrical, conical, or cord-like, and it may present secondary diverticula near its tip. It arises most frequently from the free border of the intestine, but it sometimes comes off from the side. It runs at right angles to the gut most commonly, but it may assume any direction, and it often is provided with a mesentery. In 3302 bodies specially examined with reference to its existence, it was present in 73, or 2·2 per cent, and it appeared to be more common in the male than in the female. In 59 out of the 73 cases its position with reference to the end of the ileum was examined: its average distance from the ileo-cæcal valve was $32\frac{1}{2}$ inches

measured along the gut, the greatest distance being 12 feet, and the smallest 6 inches. In 52 specimens the average length was 2·1 inches, the longest being $5\frac{1}{4}$ inches, the shortest $\frac{1}{2}$ inch. The diameter usually equals that of the intestine from which it springs; but occasionally it is cord-like, and pervious only for a short way; on the other hand, it may attain a diameter of $3\frac{3}{4}$ inches. (The foregoing results have been compiled from the reports of The Collective Investigation of the Anatomical Society of Great Britain and Ireland—L. J. Mitchell, Kelynack, Rogie, and Augier.)

Vessels and Nerves of the Jejunum and Ileum.—The **arteries** for both the jejunum and ileum—the vasa intestini tenuis—come from the superior mesenteric, and are contained between the two layers of the mesentery. After breaking up and forming three tiers of arches, the terminal branches (Fig. 683) reach the intestine, where they bifurcate, giving a branch to each side of the gut. These latter run transversely round the intestines, at first under the peritoneal coat; soon, however, they pierce the muscular coat and form a plexus in the submucosa, from which numerous branches pass to the mucous membrane, where some form plexuses around the glands of Lieberkühn, whilst others pass to the villi. The **veins** are similarly disposed, and the blood from the whole of the small intestine beyond the duodenum is returned by the superior mesenteric vein, which joins with the splenic to form the portal vein.

The **lymphatics** of the small intestine (known as lacteals) begin in the villi, and also as lymphatic sinuses surrounding the bases of the solitary glands; a large plexus is formed in the submucosa, a second between the two layers of the muscular coat, and a third beneath the peritoneum. The vessels from all these pass up in the mesentery, being connected on the way with the numerous (from 40 to 150) **mesenteric glands**, and finally unite to form one, or a few, intestinal lymphatic trunks, which open into the receptaculum chyli.

The **nerves** come from the solar plexus, through the superior mesenteric, which latter accompanies the superior mesenteric artery between the layers of the mesentery, and thus reaches the intestine. Some of the fibres are derived ultimately from the right vagus. The nerve-fibres are non-medullated, and form, as in other parts of the canal, two gangliated plexuses—that of Auerbach in the muscular coat, and the plexus of Meissner in the submucosa.

Structure.—The **serous coat** is complete in all parts of the jejunum and ileum. The **muscular coat** is much thicker in the jejunum, and grows gradually thinner as it is traced down along the ileum. The **submucosa** contains the bases of the solitary glands (Fig. 684), but otherwise calls for no special remark. The **mucous coat** is thicker and redder above, in the jejunum, thinner and paler in the ileum. It is covered throughout by villi, which are said to be shorter and broader in the jejunum, longer and narrower in the ileum. In its whole extent it is closely beset with Lieberkühn's follicles, and numerous solitary glands are seen projecting on its surface. Peyer's patches are particularly large and numerous in the ileum; they are fewer, smaller, and usually circular, in the jejunum. Finally, the mucous membrane forms valvulæ conniventes, which are largest in the jejunum; they are smaller and fewer in the upper part of the ileum, and usually disappear a little below its middle.

THE LARGE INTESTINE.

The ileum is succeeded by the large intestine (intestinum crassum), which begins on the right side, some $2\frac{1}{2}$ inches below the ileo-cæcal junction, and comprises the following parts:—

1. The **cæcum,** a wide short cul-de-sac, consisting of the portion of the large bowel below the ileo-cæcal junction. It lies in the right iliac region, and from its inner and back part a worm-shaped outgrowth, the **vermiform process,** is prolonged (Fig. 691).
2. The **ascending colon** extends from the cæcum, up in the right side of the abdomen, to the liver: here the gut bends to the left, forming the **hepatic flexure,** which connects the ascending colon to the transverse colon.
3. The **transverse colon** is a long loop of intestine which arches across the abdominal cavity in an irregular manner. It ends at the lower extremity of the spleen, where it turns downward, forming the **splenic flexure**, and passes into the descending colon.
4. The **descending colon** runs down on the left side, from the splenic flexure to the iliac crest.
5. The **iliac colon** extends from the crest of the ilium to the brim of the pelvis, where it is succeeded by the pelvic colon.
6. The **pelvic colon** is a large loop of intestine which is usually found in the pelvis. The iliac and pelvic portions of the colon taken together are commonly described as the *sigmoid flexure* of the colon.

7. The **rectum**, the terminal part of the large bowel, succeeds the pelvic colon, and ends at the **anal orifice.**

In its course the large bowel is arranged in an arched manner around the small intestine, which lies within the concavity of its curve (Fig. 670).

In *length*, the great intestine is equal to about one-fifth of the whole intestinal canal, and usually measures between 5 and 5½ feet (180 to 195 cm.). Its *breadth* is greatest at the cæcum, and from this—with the exception of a dilatation at the rectum—it gradually decreases to the anus. At the cæcum it measures, when distended, about 3 inches (75 mm.) in diameter; beyond this it gradually diminishes, and measures only 1½ inch (37 mm.) or less in the descending and iliac divisions of the colon.

The large intestine, with the exception of the rectum and vermiform appendix, may be easily distinguished from the regularly cylindrical small intestine by (*a*) the presence of three longitudinal bands—the **tæniæ coli**—running along its surface (Fig. 692); (*b*) by the fact that its walls are sacculated; and (*c*) by the presence of numerous little peritoneal processes, known as **appendices epiploicæ,** projecting from its serous coat. In addition, the larger intestine is usually wider than the small, but too much reliance cannot be placed on this character, for the jejunum is often—indeed, generally—wider than the empty descending colon.

Tæniæ Coli.—In the large bowel, unlike the small, the longitudinal fibres of the muscular coat do not form a complete layer, continuous all round the tube,

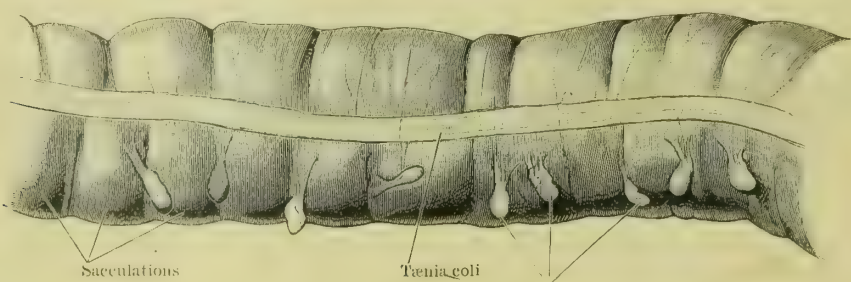


FIG. 692.—LARGE INTESTINE.

A piece of transverse colon from a child two years old. The three chief characteristics of the large intestine—sacculations, tæniæ, and appendices epiploicæ—are shown.

but, on the contrary, are broken up (Fig. 692) into three bands, known as the **tæniæ coli.** These bands, which are about ¼ inch (6 mm.) wide, begin at the base of the vermiform appendix, and run along the surface of the gut at nearly equal distances from one another until the rectum is reached. Here they spread out and form a layer of longitudinal muscular fibres, which is continuous all round the tube (see page 1036). The bands are about one-sixth shorter than the intestine to which they belong; consequently, in order to accommodate the bowel to the length of the tæniæ, the gut is tucked up, giving rise to a sacculated condition (Fig. 692). Three rows of pouches or saccules are thus produced, along the length of the tube, between the tæniæ. If the tæniæ be dissected off, the sacculations disappear, the intestine becomes cylindrical, and at the same time about one-sixth longer.

The **appendices epiploicæ** (Fig. 692) are little processes or pouches of peritoneum, generally more or less distended with fat, except in emaciated subjects, which project from the serous coat along the whole length of the large intestine, with the exception of the rectum proper.

When the interior of a piece of distended and dried large intestine is examined, its saccules appear as rounded pouches (haustra), separated by crescentic folds (plicæ semilunares coli), corresponding to the creases on the exterior separating the saccules from one another.

The position of the three tæniæ on the intestines is as follows:—On the ascending, descending, and iliac colons one tænia lies on the anterior aspect of the gut, and two behind, namely, one to the outer (postero-external), the other to the inner side (postero-internal). It is chiefly along

the first of these (the anterior) that the appendices epiploicæ are found. On the transverse colon their arrangement is different, but is rendered exactly similar by turning the great omentum, with the colon, up over the thorax. On the transverse colon in the natural position, the anterior tænia of the ascending and descending colons becomes the posterior (or postero-inferior, tænia libera), the postero-external becomes the anterior (or omental), and the postero-internal the superior or mesocolic. The anterior and postero-external tænia of the iliac colon pass below on to the front of the pelvic colon and rectum.

In formalin-hardened bodies portions of the large intestine, but particularly of the descending and sigmoid colons, are often found fixed in what appears to be a state of contraction, when they are reduced to a diameter of about $\frac{5}{8}$ or $\frac{3}{4}$ of an inch (16 to 19 mm.). Under similar conditions parts of the small intestine are found correspondingly reduced.

The appendices epiploicæ, although generally said to be absent in the fœtus, can be distinctly seen as early as the seventh month, but at this time they contain no fat.

Structure of the Large Intestine.—The **serous coat** is complete on the vermiform appendix, cæcum, transverse colon, and pelvic colon; incomplete on the ascending, descending, and iliac divisions of the colon and on the rectum. It will be described in detail with each of these portions of the intestine.

The **mucous coat** is of a pale, or yellowish, ash colour in the colon, but becomes much redder in the rectum. Unlike that of the small intestine, its surface is smooth, owing to the absence of villi, but it is closely studded with the orifices of numerous large Lieberkühn's glands. Solitary glands are also numerous, particularly in the vermiform process (Fig. 697).

Vessels and Nerves.—The cæcum and vermiform appendix receive their blood from the **ileo-colic artery**; the ascending colon from the **right colic**; and the transverse colon from the **middle colic** which lies in the transverse mesocolon. These are all branches of the superior mesenteric artery. The descending colon is supplied by the **left colic**, and the iliac and pelvic colons by the **sigmoid arteries**, branches of the inferior mesenteric. The rectum derives its blood from the three **hæmorrhoidal arteries**, which will be described with that division of the gut.

The **veins** correspond to the arteries, and join the inferior and superior mesenteric vessels, which send their blood into the portal vein.

The **lymphatics** begin in the mucous membrane, and form a large plexus in the submucosa; leaving the gut, those of the cæcum, ascending, transverse, and upper half of the descending colon, pass to the mesocolic glands, which lie behind the ascending and descending divisions of the colon and between the layers of the transverse mesocolon. The lymphatics from the lower half of the descending, and from the iliac and pelvic colons, join the left lymphatic trunk of the lumbar glands. Those of the rectum will be described later.

Nerves.—The nerves come from the superior mesenteric plexus, an offshoot of the solar plexus, and from the inferior mesenteric, a derivation of the aortic plexus. The arrangement is similar to that of the nerves of the small intestine.

THE CÆCUM AND APPENDIX.

After leaving the pelvic cavity, as already described, the terminal portion of the small intestine passes upwards, backwards, and to the right, and opens, by the ileo-cæcal orifice, into the large intestine some $2\frac{1}{2}$ inches from its lower end. The portion of the large gut which lies below the level of this orifice is known as the **cæcum** (caput cæcum coli). *In shape* (Fig. 693) it is a wide, unsymmetrical, or lop-sided cul-de-sac, furnished with the tæniæ and sacculations usually found in the large intestine. Its lower end or *fundus* is directed downwards and inwards, and usually rests on the front of the right psoas muscle, close to the brim of the pelvis; whilst the opposite end is directed upwards and outwards, and is continued into the ascending colon.

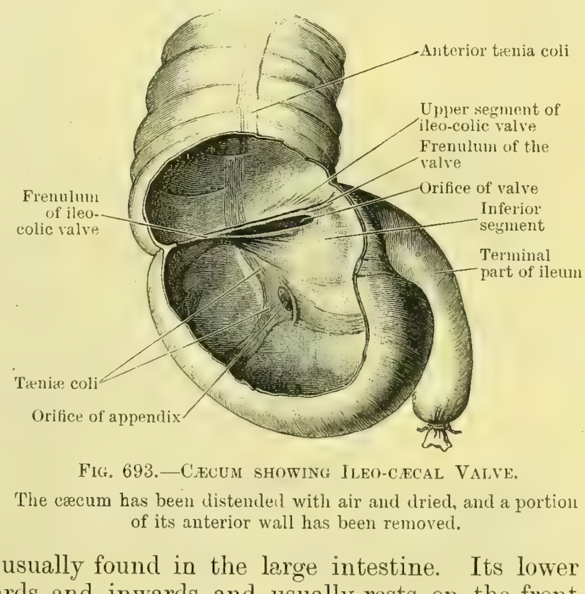


Fig. 693.—Cæcum showing Ileo-cæcal Valve.
The cæcum has been distended with air and dried, and a portion of its anterior wall has been removed.

Its unsymmetrical form is due to the fact that the outer and inner portions of the organ undergo an unequal development in the child. The inner (or inner and posterior) section lags

behind, whilst the outer (or outer and anterior) division grows much more rapidly, and, projecting downwards, soon comes to form the lower end or fundus of the cæcum. As a result the original extremity of the gut, with the vermiform process springing from it, is hidden away behind and to the inner side of the fundus.

In *length* the distended cæcum usually measures about 2½ inches (60 mm.); whilst its *breadth* is usually more, and averages about 3 inches (75 mm.).

Position.—It is situated, when normal, almost entirely within the right iliac region of the abdomen, immediately above Poupart's ligament; but its lower end projects inwards in front of the psoas and reaches the hypogastrium (Fig. 699). On the other hand, it is sometimes found, even when quite healthy, high up in the right lumbar region (owing to the persistence of the fœtal position), or hanging over the pelvic brim and dipping into the pelvic cavity to varying extents.

In the great majority of cases the cæcum is completely covered by peritoneum on all aspects, and lies quite free in the abdominal cavity. In a small proportion, namely, about 6 or 7 per cent of bodies, the posterior surface (probably as a result of adhesions) is not completely covered, but over a greater or less portion of its extent is bound down to the posterior abdominal wall by connective tissue.

Relations.—*Behind*, the cæcum rests on the ilio-psoas muscle; generally, too, on its own vermiform process and the external iliac artery. *In front*, it usually lies in contact with the anterior abdominal wall; sometimes, however, when the cæcum is empty, the small intestine intervenes. Its *outer side* is placed immediately above the outer half of Poupart's ligament (Fig. 699), whilst the *inner side* has the termination of the ileum lying in contact with it. On the inner and posterior aspect, but more on the former than the latter, the small intestine joins the cæcum. On the same aspect, and usually about 1¼ inches (31 mm.) lower down, the vermiform process comes off.

The *interior* of the cæcum corresponds in general appearance to that of the large intestine; but it presents two special features on the posterior part of its inner wall, namely, the **ileo-cæcal orifice**, guarded by the **ileo-cæcal valve**, and below this the small opening of the **vermiform appendix**, both of which call for further notice.

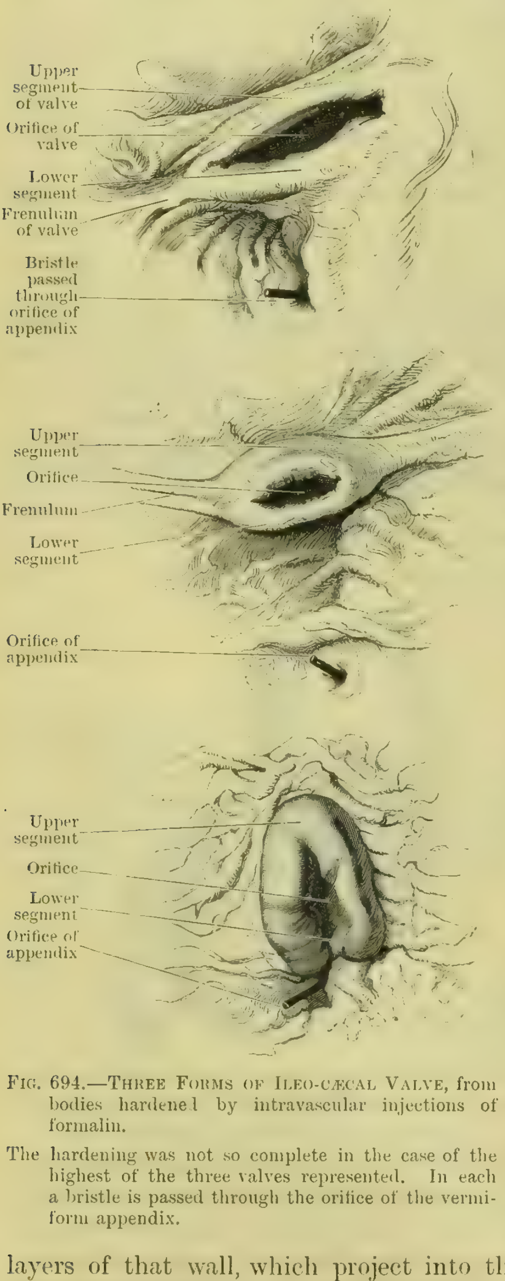


FIG. 694.—THREE FORMS OF ILEO-CÆCAL VALVE, from bodies hardened by intravascular injections of formalin.

The hardening was not so complete in the case of the highest of the three valves represented. In each a bristle is passed through the orifice of the vermiform appendix.

Ileo-cæcal Valve (valvula coli).—Where the ileum enters the large intestine, the end of the small gut is, as it were, thrust through the wall of the large bowel, carrying with it certain layers of that wall, which project into the cæcum in the form of two folds, lying respectively above and below its orifice, and constituting the two segments of the ileo-cæcal valve (Fig. 695). The condition may be compared to a partial inversion

or telescoping of the small into the large intestine: it must be added that the peritoneum and longitudinal muscular fibres of the bowel take no part in this infolding; on the contrary, they are stretched tightly across the crease produced on the exterior by the inversion, and thus serve to preserve the fold and the formation of the valve.

As seen from the interior, in specimens which have been distended and dried (Fig. 693), the valve is made up of two crescentic segments—an upper, in a more or less horizontal plane, forming the superior margin of the aperture; and a lower, which is also larger, placed in an oblique plane, and sloping upwards and inwards (*i.e.* towards the cavity of the cæcum). Between the two segments is situated the slit-shaped opening, which runs in an almost antero-posterior direction, with a rounded anterior and a pointed posterior extremity (Fig. 693). At each end of the orifice the two segments of the valve meet, unite, and are then prolonged around the wall of the cavity as two prominent folds — the **frenula** (frenula valvulæ coli). It is thought that when the cæcum is distended, and its circumference thereby increased, these frenula are put on the stretch, and, pulling upon the two segments of the valve, they bring them into apposition, and effect the closure of the orifice.

The **position of the ileo-cæcal orifice**, in the average condition, may be indicated on the surface of the body by the point of intersection of the intertubercular and Poupart lines. A point 1 to $1\frac{1}{2}$ inches (2·5 to 3·7 cm.) lower down would correspond to the **orifice of the vermiform process.**

In bodies hardened *in situ* with formalin, the valve and orifice present an entirely different appearance (see Fig. 694, in which three different forms of hardened valves are shown), suggesting, much more closely than in the dried state, the appearance of telescoping or inversion mentioned above. In them also the two segments of the valve are much thicker and shorter, but they can always be distinguished, and are found to bear the same relation to one another as in the dried condition, although this may be obscured by foldings or rugæ. The aperture may be slit-like or rounded, with sloping or infundibuliform edges; the frenula are not so prominent at times; but the whole valve projects much more abruptly into the cavity of the cæcum than in the distended and dried specimen.

Structure of the Ileo-cæcal Valve.—Each segment of the valve is formed of an infolding of all the coats of the gut, except the peritoneum and the longitudinal muscular fibres, and consequently it consists of two layers of mucous membrane, with the submucosa and the circular muscular fibres between, all of which are continuous with those of the ileum on the one hand and of the large intestine on the other. The surface of each segment turned towards the small intestine is covered with villi, and conforms in the structure of its mucous membrane to that of the ileum; whilst the mucous membrane of the opposite side resembles the mucous coat of the large bowel.

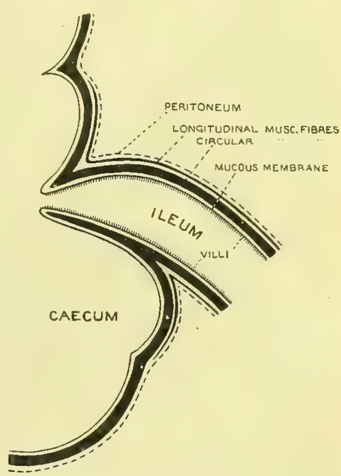


Fig. 695.—Diagrammatic Section through the Junction of Ileum with Cæcum, to show the Formation of the Ileo-cæcal Valve.

In the dried specimen the upper segment usually projects further into the cavity of the cæcum than the lower, so that the aperture appears to be placed between the edge of the lower segment and the under surface of the upper.

There is little doubt, as pointed out by Symington, that the efficiency of the ileo-cæcal valve is largely due to the oblique manner in which the ileum enters or invaginates the cæcum; this oblique passage alone, as in the case of the ureter piercing the wall of the bladder, would probably be sufficient to prevent a return of the cæcal contents. In the great majority of cases, when in position within the body, the ileum is perfectly protected from such a return, although when the parts are removed, and then distended with fluid, this often passes through the valve, and reaches the small intestine. Still, the efficiency of such a test, applied when the parts are deprived of their natural supports, cannot be relied upon.

The size of the segments of the valve, as seen in the dried condition, varies considerably; they are sometimes very imperfect; and even the absence of both has been recorded. But here again there is danger of falling into error, through examining the parts under such artificial conditions.

Development of Cæcum and Appendix.—The cæcum first appears in the embryo, at about

the fifth week, as a small outgrowth of the wall of the primitive gut (mid-gut), not yet differentiated into small and large intestines. At this time the outgrowth is of the same size throughout, and is practically equal to the intestines in diameter. About the eleventh week, whilst the large and small bowels are still of the same width, it has increased very considerably in length (being equal to about five times the diameter of the small intestine, and thus being relatively as long as in the adult); but even at this early date the basal portion, for about one-fifth of its length, is quite as wide as the intestine, whilst the remaining four-fifths of the outgrowth—the future appendix—is only about one-half or one-third the diameter of the gut. From this it is seen that the distal portion of the outgrowth, which subsequently becomes the vermiform process, begins to lag behind even at this early period of its development.

The basal portion continues to expand with the gut; the distal part grows rapidly enough in length, but otherwise enlarges very slowly, so that, towards the end of fœtal life, the cæcum has attained a conical shape, the wider end joining the ascending colon, the narrow end tapering gradually and passing into the vermiform process. This form, known as the infantile type of cæcum, is retained for some time after birth, or even may (in 2 or 3 per cent of cases) persist throughout life.

As early as the sixth or seventh month of fœtal life the wall of the terminal portion of the small intestine adheres to the inner side of the cæcum for some distance below the ileo-cæcal orifice. And this connexion, which is rendered more intimate by the passage of two folds of peritoneum, one on the front, the other on the back, between the two parts, profoundly modifies the subsequent growth of the cæcum, and determines very largely its adult form. For, when the cæcum begins to expand, the inner aspect is prevented, by its connexion with the termination of the ileum, from enlarging as freely as the rest of the wall; in consequence of this the outer part grows and expands much more rapidly, producing the lop-sided appearance already referred to, and soon comes to form the lowest part or fundus of the cæcum, and the greater part of its sac; whilst the original apex, with the vermiform appendix springing from it, anchored, as it were, to the end of the ileum, is thrust to one side, and finally lies on the inner and posterior aspect of the cæcum, a little way below, and usually posterior to, the end of the ileum.

The position of the cæcum varies at different periods of fœtal life. About the eleventh or twelfth week it lies immediately beneath the liver, and to the left of the middle line; it then gradually travels to the right, crossing the descending duodenum, and is found lying on the right side, just beneath the liver, at the fourth month. From this it descends slowly to its adult position, which it usually approaches towards the end of fœtal life, but it may not actually reach it until some time after birth. An imperfect descent gives rise to the lumbar position of the cæcum, or an excess in this direction to the pelvic position (referred to on p. 1026).

Types of Cæcum.—Three chief types of cæcum may be distinguished—the *fœtal type*, conical in shape and nearly symmetrical, with the lower end gradually passing into the vermiform appendix; the *infantile*, in which the passage from the cæcum to the vermiform process becomes more abrupt, the outer wall more prominent, and the whole sac more unsymmetrical; and the lop-sided *adult form*, as described above, which is the condition found in 93 or 94 per cent of adults.

Structure.—Nothing in the arrangement of the mucous and submucous coats calls for special notice. The tæniæ or longitudinal bands of the muscular coat all spring from the base of the vermiform appendix (Fig. 696); the anterior runs up on the front, internal to the main prominence of the cæcum; the postero-external runs up behind this prominence; whilst the postero-internal passes directly upwards behind the ileum (Fig. 696). The longitudinal fibres on the upper aspect of the ileum partly join the postero-internal tænia; those on the front and back join the circular fibres of the large gut.

The serous coat has, in connexion with it, certain folds and fossæ which are described at p. 1030.

Vermiform Process or Appendix Cæci (Fig. 698).—The appendix is a worm-like tubular outgrowth which springs from the inner and back part of the cæcum about 1 to $1\frac{1}{2}$ inches (2·5 to 3·75 cm.) below the ileo-cæcal orifice. From this it generally runs in one of three chief directions, namely—(1) over the brim, into the pelvis; (2) upwards behind the cæcum; or (3) upwards and inwards towards the spleen: each of which has been considered to be the normal position by one or more observers. In the first of these situations it is quite evident as it hangs over the pelvic brim; in order to expose it in the second, the cæcum must be turned upwards; whilst, in the third position, it lies behind the end of the ileum and its mesentery, and these must be raised up in order to display it. In addition to the positions just mentioned, it has been found in almost every possible situation in the abdomen which its length would allow it to attain. In every case the anterior tænia of the cæcum, which is always distinct, offers the surest guide to the process, the base of which can be located with certainty by following this tænia to the back of the cæcum (Fig. 696).

Its size is almost as variable as its position. Taking the average of numerous measurements, its length may be given as about $3\frac{1}{2}$ inches (92 mm., Berry), and its

breadth as $\frac{1}{4}$ inch (6 mm., Berry). On the other hand, it has been found as long as 9 inches (230 mm.), and as short as $\frac{3}{4}$ inch (18 mm.). Even its absence has been recorded (Fawcett).

Its *lumen* or *cavity* is variable in its development, and is found to be totally or partially occluded in at least one-fourth of all adult and old bodies examined. This is looked upon as a sign of degeneracy in the process, which is by many considered to be undergoing a gradual obliteration in the human species. It opens into the cavity of the cæcum on its inner, or inner and posterior aspect (Fig. 693), at a point 1 to $1\frac{1}{2}$ inches (2·5 to 3·8 cm.) below, and somewhat behind the ileo-cæcal orifice. These are the relative positions of the two orifices, as seen from the interior of the cæcum; viewed from the exterior, the base of the appendix is within $\frac{3}{4}$ inch of the lower border of the ileum. This apparent difference is due to the fact that the ileum adheres to the inner side of the cæcum for a distance of nearly 1 inch before it opens into it.

Sometimes the orifice of the appendix has a crescentic fold or valve (valvula processus vermiformis) placed at its upper border; but it is probably of very little

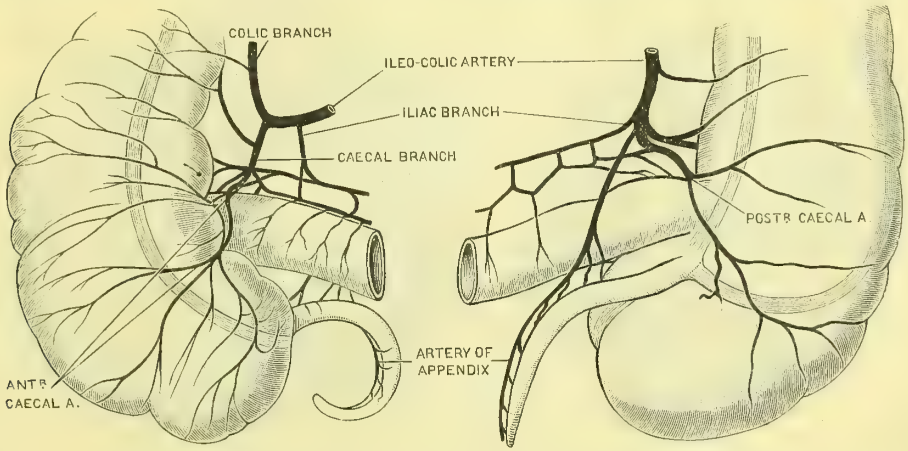


Fig. 696.—The Blood Supply of the Cæcum and Vermiform Appendix.

The illustration to the left gives a front view, in that to the right the cæcum is viewed from behind. In the latter the artery of the appendix, and the three tænia coli springing from the base of the appendix, should be specially noted (modified from Jonnesco).

functional importance when present, for the aperture of the appendix is usually so small that its cavity is not likely to be invaded by the contents of the cæcum.

The vermiform process is completely covered by peritoneum, and has a considerable mesentery, the *meso-appendix* (mesenteriolum processus vermiformis), which extends to its tip as a rule, and connects the process to the under surface of that part of the mesentery proper which goes to the lower end of the ileum.

The appendix is relatively, to the rest of the large intestine, longer in the child at birth than in the adult, the proportion being about 1 to 16 or 17 at birth and 1 to 19 or 20 in the adult. (The difference is certainly not as great as stated by Ribbert, who makes the proportion 1 to 10 at birth and 1 to 20 in the adult.) The process attains its greatest length and diameter during adult and middle age, and atrophies slowly after that time. It is said to be slightly longer in the male than in the female.

Total occlusion of its cavity is found in 3 or 4 per cent of bodies; it is then converted into a fibrous cord. Partial occlusion is present in 25 per cent of all cases, and in more than 50 per cent of those over 60 years old, whilst it is unknown in the child. This frequency of occlusion, the physiological atrophy which takes place after middle life, the great variations in length, and other signs of instability, have been considered to point to the retrogressive character of the appendix.

A vermiform process is found only in man, the higher apes, and the wombat, although in certain rodents a somewhat similar arrangement exists. In carnivorous animals the cæcum is very slightly developed; in herbivorous animals (with a simple stomach) it is, as a rule, extremely large. It has been suggested that the vermiform process in man is the degenerated remains of the herbivorous cæcum, which has been replaced by the carnivorous form. Another and perhaps more probable view regards the appendix as a lymphoid organ, having the same functions as Peyer's patches, and like these undergoing degeneration after middle life (Berry).

In the fœtus and child, as well as in the adult with the infantile type of cæcum, the appendix springs from the true apex, not from the inner and posterior aspect.

Foreign bodies, although reputed to find their way very easily into the appendix, are rarely found there after death. On the other hand, concretions or calculi, formed of mucus, fæces, and various salts, are often present (Berry).

Structure (Fig. 697).—The **serous coat** is complete, and forms a perfect investment for the process. The **muscular coat**, unlike that of the rest of the large intestine, has a continuous and stout layer of longitudinal fibres, which passes at the root of the process into the three tæniæ coli (Fig. 698). The layer of circular fibres is well developed. The **submucosa** is almost entirely occupied by large masses of lymphoid tissue surrounded by sinus-like lymph spaces. Owing to the large size of these lymphoid nodules, the areolar tissue of the submucosa is compressed against the inner surface of the muscular coat, and forms a well-marked fibrous ring, which sends processes at intervals between the lymphoid masses towards the mucous membrane. The inner portion of this fibrous ring seems to have been generally mistaken for the muscularis mucosæ, which latter, as seen in Fig. 697, lies internal to the chief masses of lymphoid tissue, and not outside it, as figured by Testut. These lymphoid nodules, which correspond to solitary glands, have, owing to

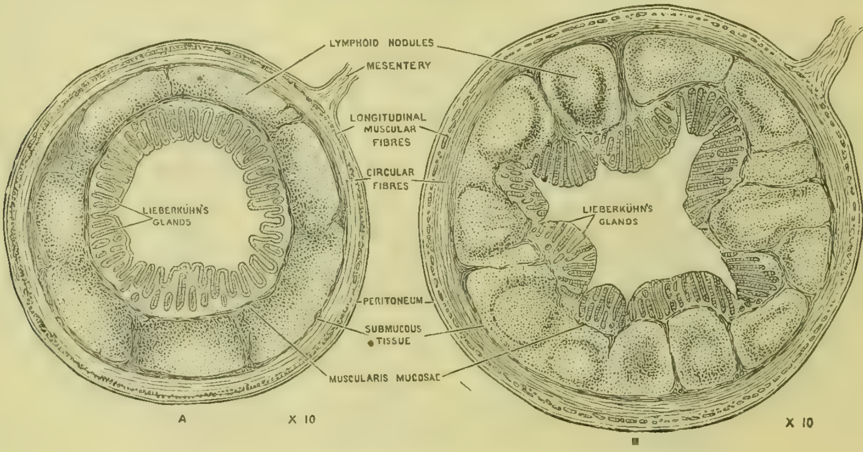


Fig. 697.—Structure of the Vermiform Appendix.

A. From a child two years old. B. From a male, age 56.

It will be observed that the submucosa is almost entirely occupied by lymphoid nodules and patches. The muscularis mucosæ is very faint, and lies quite close to the bases of Lieberkühn's glands. The longitudinal layer of muscular fibres forms a continuous sheet.

their great number, been almost completely crushed out of the mucosa (in which they chiefly lie in the intestine) into the submucosa.

The **mucous coat** corresponds to that of the large intestine in its general characters, but the Lieberkühn's glands are fewer, and irregular in their direction; the muscularis mucosæ is thin and ill-defined; it lies just internal to the lymphoid nodules of the submucosa, and immediately outside the base of Lieberkühn's glands. Some few lymphoid nodules lie in the mucous coat also.

Blood-vessels of the Cæcum and Vermiform Appendix (Fig. 696).—These parts are supplied with blood by the **ileo-cæcal artery**. This gives off, near the upper angle formed by the junction of the ileum with the small intestine—(*a*) an *anterior cæcal artery*, which passes down on the front of the ileo-cæcal junction to the cæcum, and breaks up into numerous branches for the supply of that part; (*b*) a *posterior cæcal artery*, similarly disposed on the back; and (*c*) the *artery of the appendix*. The last-named branch passes down behind the ileum (Fig. 696), then enters the mesentery of the appendix, and running along this near its free border, sends off several branches across the little mesentery to the appendix, before finally ending in it. The course of the artery behind the ileum is said to render it subject to pressure from fæcal masses in that gut, and thus to predispose to an interference with the supply of the appendix, and morbid changes in the process. It has also been said that the appendix receives a small branch from the left ovarian artery in the female—a statement which I have been unable to verify.

The **veins** correspond to the arteries. The **lymphatics** pass with the vessels to join a few small glands which are found in the mesentery of the appendix at its base, the efferent vessels from which join the mesocolic glands behind the ascending colon.

Cæcal Folds and Fossæ.—The peritoneum forms in the neighbourhood of the

cæcum certain fossæ, of which the most interesting and important are—(*a*) the retro-cæcal or retro-colic fossæ; (*b*) the ileo-cæcal fossa; and (*c*) the ileo-colic fossa.

The **retro-colic fossæ** (Fig. 698, B) are only occasionally present, and are exposed by turning the cæcum and adjacent part of the ileum upwards. Two forms, external and internal, are described; the first lies behind the outer part of the ascending colon, immediately above the cæcum; the second behind its inner part. These fossæ are specially interesting because, when present, they frequently lodge the vermiform process (see Fig. 698, B), a condition which is said to favour the production of appendicitis.

Ileo-cæcal Fossa and Fold.—If the appendix be drawn down, and the finger run towards the cæcum, along the *lower* border of the terminal part of the ileum, its point will generally run into a fossa situated in the angle between the ileum and cæcum (Fig. 698, A), which is known as the ileo-cæcal fossa. The fold which bounds the fossa in front is the ileo-cæcal fold (the "bloodless fold of Treves"). It passes from the ileum to the front of the meso-appendix, which latter forms the posterior wall of the fossa.

Ileo-colic Fold and Fossa.—Similarly, if the finger be run out along the *upper* border of the ileum towards the cæcum, it will usually lodge in a smaller fossa, the ileo-colic, which

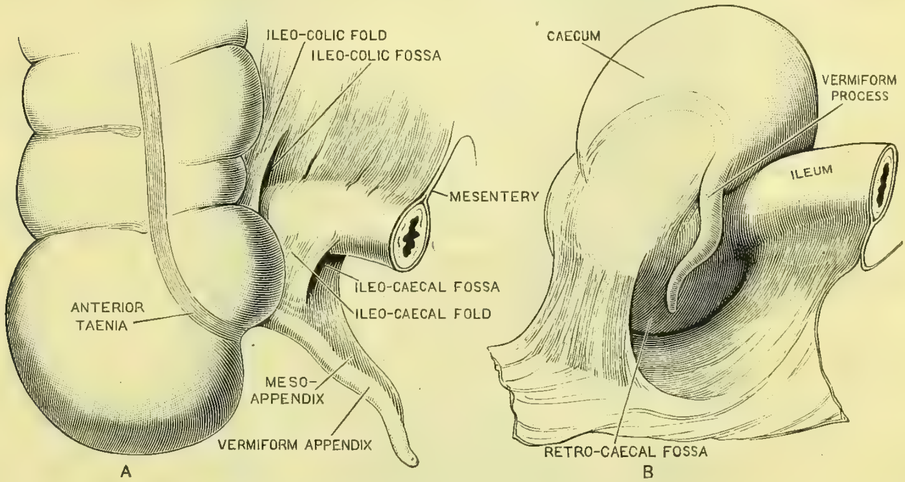


FIG. 698.—THE CÆCAL FOLDS AND FOSSÆ.

In A, the cæcum is viewed from the front; the mesentery of the appendix is distinct, and is attached above to the under surface of the portion of the mesentery going to the end of the ileum. In B, the cæcum is turned upwards to show a retro-cæcal fossa, which lies behind it and the beginning of the ascending colon.

is bounded in front by a small peritoneal process, the ileo-colic fold (Fig. 698, A), containing the anterior cæcal artery.

THE COLON.

The **ascending colon** (colon ascendens) begins about the level of the intertubercular line, opposite the ileo-cæcal orifice, where it is continuous with the cæcum. From this it runs upwards and somewhat backwards, with a slight concavity to the left, until it reaches the under surface of the liver, where it bends forwards and to the left, and passes into the hepatic flexure (Fig. 699). In its course it lies in the angle between the quadratus lumborum behind, and the more prominent psoas internally (Fig. 673).

It is situated chiefly in the right lumbar region, but it extends slightly into the hypochondrium above; and, although it usually begins about the level of the intertubercular line, still with a low position of the cæcum it will extend further down, and may occupy a considerable part of the iliac region.

Its *length* is about 8 inches (20 cm.), and it is wider and much more prominent than the descending colon. It generally presents several minor curves or flexures, and it often has the appearance of being pushed into a space which is too short to accommodate it.

Relations.—*In front,* it is usually in contact with the abdominal wall, but the small intestine frequently intervenes, particularly above (Fig. 670). To its *inner*

side lie the coils of the small bowel and the psoas; to the *outer side* is the lateral wall of the abdomen. Its *posterior surface*, which is free from peritoneum as a rule (Fig. 673), is connected by areolar tissue to the iliacus muscle as far up as the crest of the ilium, to the quadratus lumborum above this, and finally to the lower and outer part of the right kidney.

In the great majority of cases only the two sides and the anterior surface are covered by peritoneum, the posterior surface being destitute of a serous coat (Fig. 673). In a small proportion of bodies, however, the ascending colon is provided with a complete peritoneal coat and a mesentery, but this latter is so short that it admits of but a slight amount of movement in the gut.

Like the cæcum, the ascending colon is frequently found distended with gas or fæces after death, hence in part its large size and prominence as compared with the descending colon, which is generally empty.

Hepatic Flexure (flexura coli dextra).—The hepatic flexure is the bent piece of the large intestine between the end of the ascending and the beginning of the transverse colons (Figs. 688 and 699).

When the ascending colon, lying on the front of the kidney, reaches the under surface of the liver, it bends—usually acutely, sometimes obtusely—forwards and to the left, and on reaching the front of the descending duodenum, passes into the transverse colon.

The flexure is placed between the descending duodenum internally and the lower thin margin of the liver, or the lateral abdominal wall, externally; above, it corresponds to the colic impression on the liver, and behind it rests on the kidney. Its peritoneal relations are similar to those of the ascending colon.

Transverse Colon (colon transversum).—This is the long and arched portion of the large intestine which lies between the hepatic and splenic flexures. It begins where the colon crosses the descending duodenum at the end of the hepatic flexure (Fig. 699). From this it runs transversely to the left, and for the first few inches is comparatively fixed, being united to the front of the descending duodenum and the head of the pancreas either by a very short mesentery or by areolar tissue. Immediately beyond this a long mesentery is developed, which allows the colon to hang down in front of the small intestine, at a considerable distance from the posterior abdominal wall. Towards its left extremity the mesentery shortens again, thus bringing the gut towards the tail of the pancreas (Fig. 688), along which it runs upwards into the left hypochondrium, under cover of the stomach, as far as the lower end of the spleen, where it passes into the splenic flexure (Fig. 687). Its two ends lie in the right and left hypochondriac regions respectively, whilst its middle portion hangs down into the umbilical, or even the hypogastric region.

Its average *length* is about 19 or 20 inches (47·5 to 50·0 cm.), that is more than twice the distance, in a direct line, between its two extremities. This great length is accounted for by the very irregular course which the bowel pursues.

Relations.—The greater part of the transverse colon lies behind the great omentum, which must consequently be turned upwards in order to expose it. *Above*, it is in contact, from right to left (Fig. 699), with the liver and gall-bladder, the stomach, and, near its left end, with the tail of the pancreas and lower end of the spleen (Fig. 688). *In front* are placed the omentum and the anterior abdominal wall; towards its termination the stomach is likewise in front. *Behind*, it first lies in contact with the descending duodenum and head of the pancreas; beyond this, where it hangs down, the small intestine is placed below and behind, and it is connected to the posterior abdominal wall (more correctly, to the anterior border of the pancreas) by the transverse mesocolon. It is also loosely connected to the stomach by the great omentum, which is attached to its anterior surface. The transverse mesocolon and the great omentum are described with the peritoneum, p. 1046.

The transverse colon is completely covered by peritoneum, with the exception of the first few inches of its posterior surface, which are often, if not usually, uncovered.

The state of the peritoneal covering on the back of the first part of the transverse colon would seem to depend, in some degree, on the extent to which the liver passes downwards on the right side. With a small high liver no mesentery is present, and the posterior surface is devoid of peritoneum; on the other hand, when the liver is enlarged in the vertical direction, it pushes the colon downwards before it, and brings the upper line of the peritoneal reflection from its back, into contact with the lower, thus giving rise to the mesentery. In the fœtus of three or four months every part of the colon is supplied with a long mesentery; subsequently this, as a rule, disappears at the beginning of the transverse colon, but it may be reproduced in the manner stated.

Splenic Flexure (flexura coli sinistra).—The terminal portion of the transverse colon runs upwards (also backwards and to the left) until the lower end or base of the spleen is reached; here it bends sharply, forming the splenic flexure,

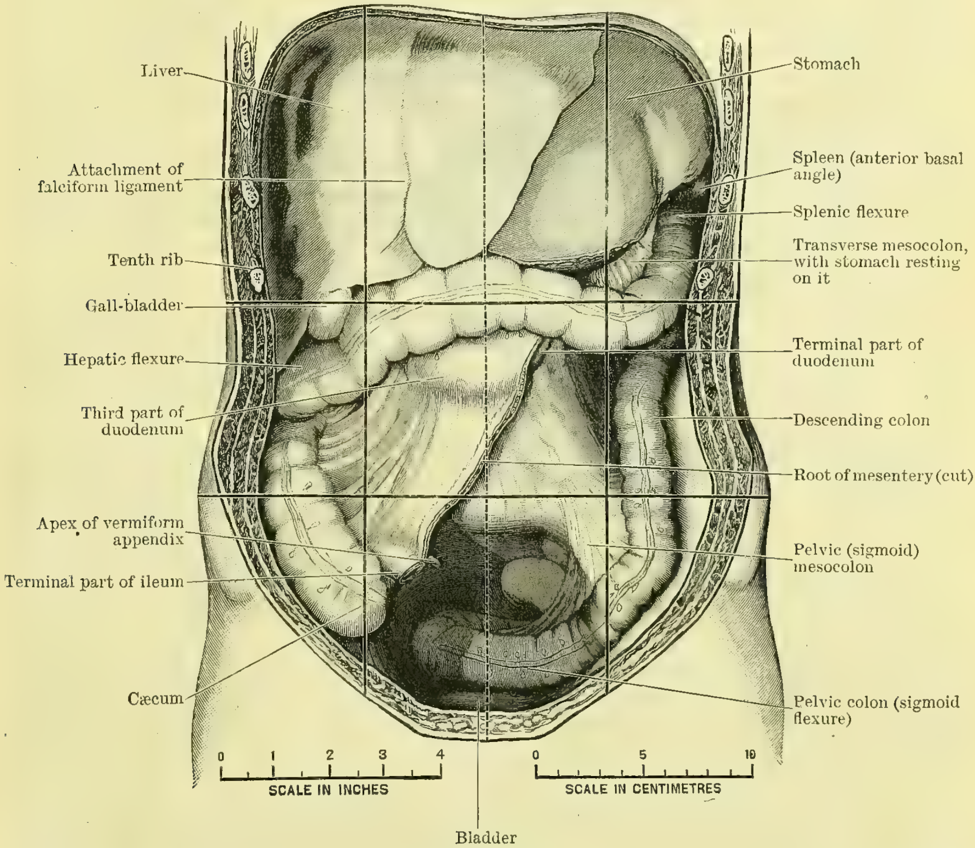


FIG. 699.—THE ABDOMINAL VISCERA AFTER THE REMOVAL OF THE JEJUNUM AND ILEUM (from a photograph of the same body as depicted in Fig. 670). The transverse colon is much more regular than usual. Both the liver and cæcum extend lower down than normal. The subdivisions of the abdominal cavity are indicated by dark lines.

and runs down into the descending colon. The flexure is placed deeply in the left hypochondrium, behind the stomach, and in contact with the base of the spleen. It lies at a higher level than the hepatic flexure, and is connected to the abdominal parietes by the phreno-colic ligament, which helps to maintain it in this position.

Phreno-colic or Costo-colic Ligament (ligamentum phrenocolicum, Fig. 688).—This is a triangular fold of peritoneum, with a free anterior border, which is attached internally to the splenic flexure and externally to the diaphragm opposite the eleventh rib. Owing to the fact that the base of the spleen rests upon it, the ligament has also received the name of **sustentaculum lienis**.

The phreno-colic ligament is formed in the fœtus from the left margin of the great omentum (Jonnesco and Fig. 688).

The peritoneal covering of the splenic flexure is similar to that of the descending colon.

Descending Colon (colon descendens).—This is much narrower and less obtrusive than the ascending colon. It begins in the left hypochondrium at the splenic flexure, passes down on the left side of the abdomen, and ends in the lumbar region, opposite the crest of the ilium, by passing into the iliac colon. Its course is not quite straight, for it first curves downwards and inwards along the outer side of the left kidney, and then descends almost vertically to the iliac crest (Fig. 699).

Its *length* is usually from 4 to 6 inches (10 to 15 cm.), and its *width*, which is very much less than that of the ascending colon, about 1½ inches (37 mm.).

Relations.—The descending colon first lies in contact with the outer aspect of the left kidney; below this it descends, like the colon of the opposite side, in the angle between the psoas and quadratus lumborum muscles. *Behind*, it rests upon the lower part of the diaphragm above, and on the quadratus lumborum below. *In front* (and somewhat to the outer side also, except when the bowel is distended) are placed numerous coils of small intestine, which hide the colon completely from view, and compress it against the posterior abdominal wall in such a way that, at first sight, it may be overlooked in a fat body. To its *inner side* lies the lower part of the kidney above, the psoas below.

In the great majority of bodies only the front and sides of the descending colon are covered by peritoneum (Fig. 709); the posterior surface, being destitute of a serous coat, is connected to the posterior wall of the abdomen by areolar tissue. In a small proportion of cases, on the other hand, the serous coat is complete, and the colon is furnished with a short mesentery.

Up to the fourth or fifth month of fœtal life the descending colon has a complete investment of peritoneum and a long mesentery. After the fifth month the mesentery adheres to, and soon blends with, the parietal peritoneum on the posterior abdominal wall, and is completely lost as a rule. The persistence of this mesentery, in a greater or less degree, explains the occasional presence of a descending mesocolon in the adult.

Sigmoid Flexure and Rectum.—It has been customary to divide the remaining portion of the large intestine into sigmoid flexure and rectum. The former was said to begin at the crest of the ilium, to lie in the iliac fossa, and to end at the brim of the pelvis. Or, in later years, the "sigmoid colon" was described as "that part of the colon which is attached to the left iliac fossa, from the iliac crest to the brim of the true pelvis" (Symington). Its upper part was said to be covered by peritoneum on the anterior and lateral surfaces only, its lower part to form a large loop with a complete serous coat and a long mesentery, which hung down into the pelvic cavity when the bladder and rectum were empty, and passed up out of it when these were distended.

The rectum was described as beginning at the brim of the pelvis, opposite the left sacro-iliac joint, and as ending at the anus. It was divided into three portions, of which the first extended from the brim of the pelvis to the middle of the third piece of the sacrum, had a complete covering of peritoneum, and was connected to the pelvic wall by a mesentery—the mesorectum. The second and third parts of the rectum we may pass over for the present, as they agree in general with the description of the rectum given below.

Treves in 1885, and Jonnesco in 1889, directed attention to the fact that no such loop as the classical sigmoid flexure, lying in the iliac fossa, was to be found in nature; and also, that the separation of the first portion of the rectum from the sigmoid flexure—so-called—was both artificial and inaccurate. They pointed out that the "first part of the rectum" really belongs to the sigmoid flexure, with which it has everything in common, and that on no grounds can it be properly assigned to the rectum.

An unbiassed study of the parts concerned, particularly in bodies the viscera of which have been hardened *in situ*, will leave little doubt on an unprejudiced mind that the old descriptions are not only artificial but erroneous. Consequently, the admirable account of this part of the intestine, given by Jonnesco, will be followed in its main features in describing the divisions of the bowel heretofore known as the sigmoid flexure and first part of the rectum.

Jonnesco, recognising that this portion of the intestine lies partly in the iliac fossa and partly in the pelvis, very appropriately calls the former the iliac colon and the latter the pelvic colon. The **iliac colon** includes the portion of the "sigmoid flexure" which extends from the crest of the ilium to the inner side of the psoas muscle (that is practically the brim of the pelvis), and is usually destitute of a mesentery. The **pelvic colon** embraces the remainder of the "sigmoid colon" and the first part of the rectum, both of which are attached by a continuous mesentery, and form one large loop lying in the pelvic cavity, and ending at the level of the third sacral vertebra by passing into the **rectum proper**.

Iliac Colon (colon iliacum).—This corresponds to the portion of the "sigmoid flexure" which lies in the iliac fossa, and it has no mesentery. It is the direct continuation of the descending colon, with which it agrees in every detail, except as regards its relations. Beginning at the crest of the ilium, it passes downwards

and somewhat inwards, lying in front of the iliacus muscle. A little way above Poupart's ligament it turns inwards over the psoas, and ends at the inner border of this muscle by dipping into the pelvis and becoming the pelvic colon (Fig. 699). It usually measures about 5 or 6 inches (12·5 to 15 cm.) in length, but it varies considerably in this respect.

Relations.—*Behind,* it lies upon, and, as a rule, is connected by areolar tissue to, the front of the ilio-psoas muscle. *In front,* it is usually covered by coils of small intestine, which hide it from view; but when distended, or when it occupies a lower position than usual, it comes into direct contact with the anterior abdominal wall. As a rule (90 per cent of bodies—Jonnesco), it is covered by peritoneum only on its anterior and two lateral surfaces. Occasionally (10 per cent of cases) it is completely covered, has a short mesentery (1 inch, 2 to 3 cm.), and is slightly movable.

In its course it passes down over the iliac fossa near its middle, generally forming a curve with its concavity directed inwards and upwards, and having reached a point $1\frac{1}{2}$ or 2 inches (4 to 5 cm.) above Poupart's ligament, it turns inwards across the psoas towards the pelvic cavity. Occasionally the iliac colon occupies a lower position than usual, and runs along the deep surface of Poupart's ligament, immediately behind the anterior abdominal wall.

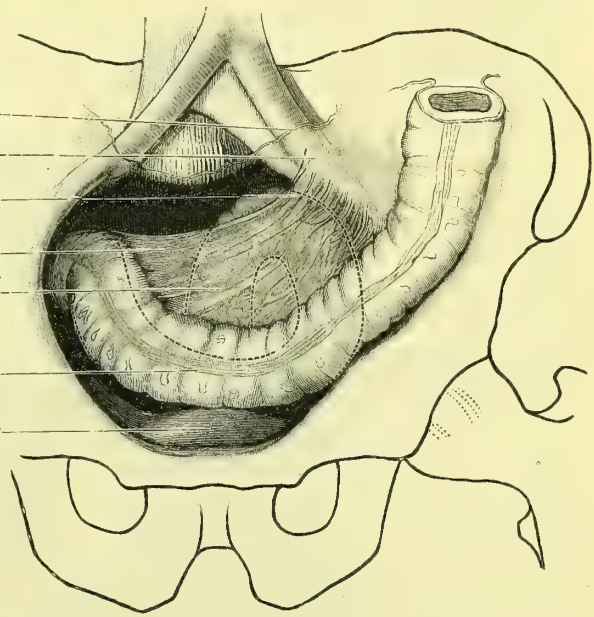


FIG. 700.—THE ILIAC AND PELVIC COLONS, from a formalin-hardened male body, aged 30.

The pelvic colon was unusually long; its course is shown, as well as that of the beginning of the rectum, by dotted lines. It first ran across the upper surface of bladder to the right pelvic wall, then recrossed the pelvis in a line posterior to its first crossing; finally it returned towards the middle line, and passed into the rectum. As a rule, after crossing to the right side of the pelvis, the pelvic colon turns backwards and inwards to reach the middle line, where it passes into the rectum.

Pelvic Colon (colon pelvinum).—This corresponds to the portion of the "sigmoid flexure" which lies in the pelvis, together with the so-called "first part of the rectum." The pelvic colon is a large coil of intestine, which begins at the inner border of the left psoas muscle, where it is continuous with the iliac colon, and ends at the level of the third sacral vertebra by passing into the rectum proper. Between these two points it has a well-developed mesentery, and forms a large and variously-shaped coil, which usually lies in the cavity of the pelvis (93 per cent).

Whilst the loop of the pelvic colon is very irregular in form, the following may be given as perhaps its most common arrangement. Beginning at the inner margin of the left psoas, it first plunges over the brim into the pelvis, and crosses this cavity from left to right; it next bends backwards and then returns along the posterior wall of the pelvis towards the middle line, where it turns down and passes into the rectum (Figs. 699 and 700).

Relations.—In its passage into the pelvis it crosses the external iliac vessels; in running from left to right across the cavity, it rests on the bladder or uterus, according to the sex; whilst above it lie the coils of the small intestine.

It is completely covered by peritoneum, and is furnished with an extensive mesentery—the pelvic mesocolon—which permits of considerable movement.

Sometimes, when longer than usual (Fig. 700), the pelvic colon, in returning from the right side of the pelvis, crosses the middle line, going even as far as the left wall, and then turns

back a second time towards the middle of the sacrum, where it joins the rectum at the usual level, thus making an S-shaped curve within the pelvis. On the other hand, when the loop is short (a not infrequent occurrence), all its curves are abridged, and it fails to pass over to the right side, but runs more or less directly backwards after entering the pelvis.

From what has been said, it will be seen that the loop of the pelvic colon is subject to numerous and considerable variations, which are chiefly dependent upon its length and that of its mesentery, and also upon the state of emptiness or distension of itself and of the other pelvic viscera. When the intestine is long the loop is more complex; when short, more simple. When the bladder and rectum are distended, or when the pelvic colon itself is much distended, it is unable to find accommodation in the true pelvis, and consequently it passes up into the abdominal cavity, almost any part of the lower half of which it may occupy. But, as already stated, in the great majority of cases (92 per cent, according to Jonnesco) it is found after death lying entirely within the pelvic cavity.

In *length*, the pelvic colon generally measures about 16 or 17 inches (40 to 42·5 cm.), but it may be as short as 5 inches (12 cm.), or as long as 35 inches (84 cm.).

The **pelvic mesocolon**, which corresponds to both the sigmoid mesocolon and the meso-rectum, is a fan-shaped fold, short at each extremity, and long in its middle portion (Figs. 699 and 700). Its root is attached along an inverted V-shaped line, one limb of which runs up close to the inner border of the left psoas, as high as the bifurcation of the common iliac artery (or often higher); here it bends at an acute angle, and the second limb descends over the sacral promontory and along the front of the sacrum to the middle of its third piece, where the mesentery ceases, and the pelvic colon passes into the rectum. When the pelvic colon ascends into the abdominal cavity, this mesentery is doubled up on itself, the side, which was naturally posterior, becoming anterior.

Intersigmoid Fossa (recessus intersigmoideus).—When the pelvic colon with its mesentery is raised upwards, a small orifice will usually be found beneath the mesentery, corresponding to the apex of the V-shaped attachment of its root to the posterior abdominal wall. This orifice leads into a fossa which is directed upwards, and will often admit the last joint of the little finger. It is known as the *intersigmoid fossa*, and is due to the imperfect blending of the mesentery of the descending colon of the fœtus with the parietal peritoneum. In the fœtus this mesentery is well developed, and extends from the region of the vertebral column out towards the descending colon. After a time it begins to unite with the underlying parietal peritoneum; but in the region of the intersigmoid fossa the union is rarely perfect, hence the presence of the fossa.

In the **child at birth** only the terminal part of the pelvic colon lies in the pelvis. This is chiefly owing to the small size of the pelvic cavity in the infant. Beginning at the end of the iliac colon, the pelvic colon generally arches upwards and to the right across the abdomen towards the right iliac fossa, where it forms one or two coils, and then passes down over the right side of the pelvic brim into the pelvic cavity. In cases of imperforate anus, it is important to remember, in connexion with the operation for forming an artificial anus, that, whilst the iliac colon is found in the left iliac region, the pelvic colon ("sigmoid flexure") usually lies on the right side, and passes over the right portion of the brim to enter the pelvis.

Structure of the Pelvic Colon.—Only the arrangement of the muscular coat need be referred to. As the tæniæ of the descending colon are followed down, it will be found that the postero-external band gradually passes on to the front, and unites with the anterior tænia to form a broad band, which occupies nearly the whole width of this bowel in its lower portion. The postero-internal tænia spreads out in a similar manner on the back; so that in the lower half of the pelvic colon the longitudinal layer of the muscular coat is complete, with the exception of a narrow part on each side; here the circular fibres come to the surface, and the intestine presents a series of small sacculations. These, however, disappear, and the longitudinal fibres, although thicker in front and behind, form a continuous layer all round, as the rectum proper is approached.

THE RECTUM.

The **rectum** proper (intestinum rectum: second portion of the rectum of the usual descriptions) is the comparatively dilated portion of the large bowel which intervenes between the pelvic colon above and the anal canal—the slit-like passage through which it communicates with the exterior (Fig. 701). It forms a temporary reservoir, in which the fæces accumulate a short time before they are discharged from the body, but as a result of habit this temporary function may be converted into a more or less permanent one.

Unlike the portion of the bowel which immediately precedes it, the rectum has but a partial covering of peritoneum, and is entirely destitute of a mesentery; sacculations, too, which are so characteristic of the large intestine, cannot properly be said to be present.

The rectum begins at the termination of the pelvic mesocolon, namely, about the level of the third sacral vertebra, and ends, where the bowel pierces the pelvic floor, opposite the lower and back part of the prostate in the male, or at a point $1\frac{1}{2}$ inches (3·7 cm.) in front of, but at a lower level than, the tip of the coccyx in both sexes. It first descends along the front of the sacrum and coccyx, following the curve of these bones; beyond the coccyx, it rests, for about $1\frac{1}{2}$ inches (3·7 cm.), on the back part of the pelvic floor, here formed by the union of the two levatores ani; and finally, having reached the lower part of the prostate, it bends rather abruptly backwards and downwards, and, piercing the pelvic floor, passes into the anal canal (Fig. 704).

Its general direction is downwards, but this varies at its two extremities, being downwards and backwards above, downwards and strongly forwards below.

Curvatures.—The rectum is far from straight, notwithstanding its name,

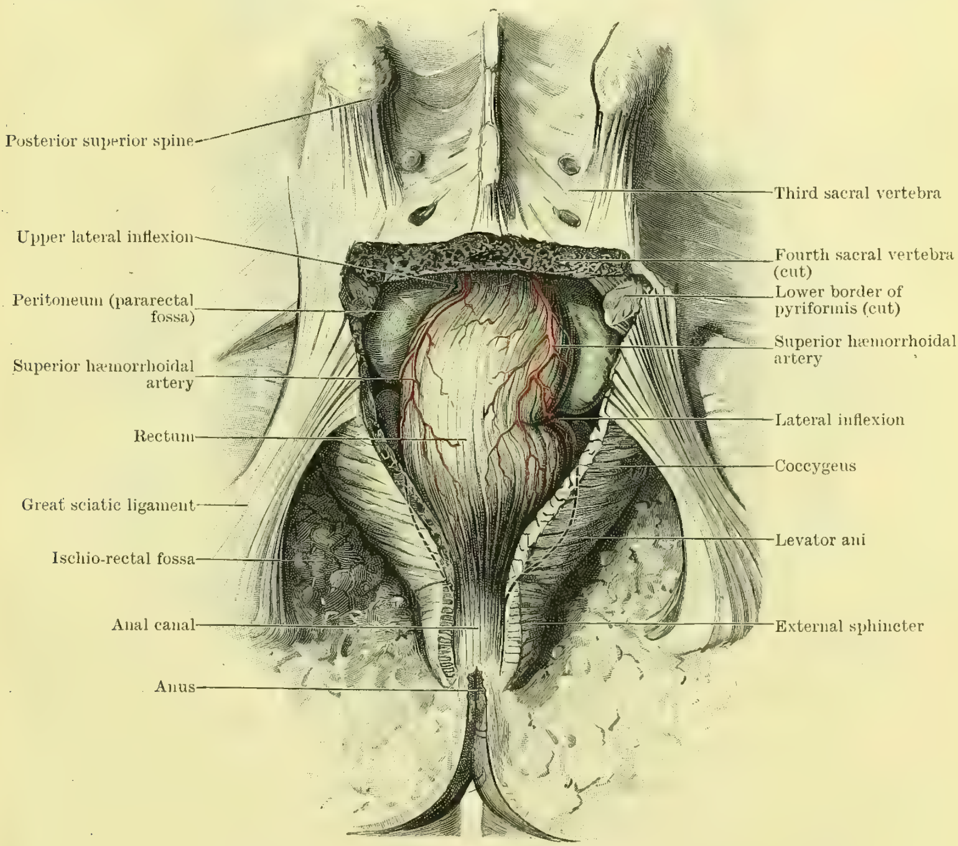


Fig. 701.—The Rectum from behind.

The sacrum has been sawn across through the 4th sacral vertebra, and its lower part removed with the coccyx. The posterior portions of the coccygei, levatores ani, and of the external sphincter have been cut away. The "pinching in" of the lower end of the rectum by the inner edges of the levatores ani, resulting in the formation of the flattened anal canal, is suggested in the illustration, which has been made from a formalin-hardened male body, aged thirty. The lateral inflexions of the rectum, corresponding to Houston's valves, are also shown.

which describes its condition fairly accurately in most animals, but not in man, in whom it is curved in both the antero-posterior and the transverse planes. Viewed *from the side* (Fig. 737), it forms a gentle curve, with the convexity backwards, which extends from the beginning of the rectum to the back of the prostate, and fits into the hollow of the sacrum and coccyx. At the back of the prostate a second curve is formed where the rectum joins the anal canal; this has its convexity directed forwards, whilst its concavity embraces the **ano-coccygeal body**—the mass of muscular and connective tissue which lies between the tip of the coccyx and the anal canal.

When *viewed from the front* the rectum is seen to be regularly folded from side to side in a zigzag fashion, the folding being slightly marked when the rectum is empty, but becoming much more distinct with distension (Figs. 702 and 703). In other words, when viewed from this aspect it presents, in the majority of cases, three more or less distinct lateral flexures or inflexions. Of these the upper and lower have their concavities directed to the left as a rule; the third flexure, which is the best marked, lies between the other two, but on the right side. Not infrequently, however, two are found on the right and one on the left side. The flexures, which are marked on the exterior by a crease, appear in the interior as three prominent

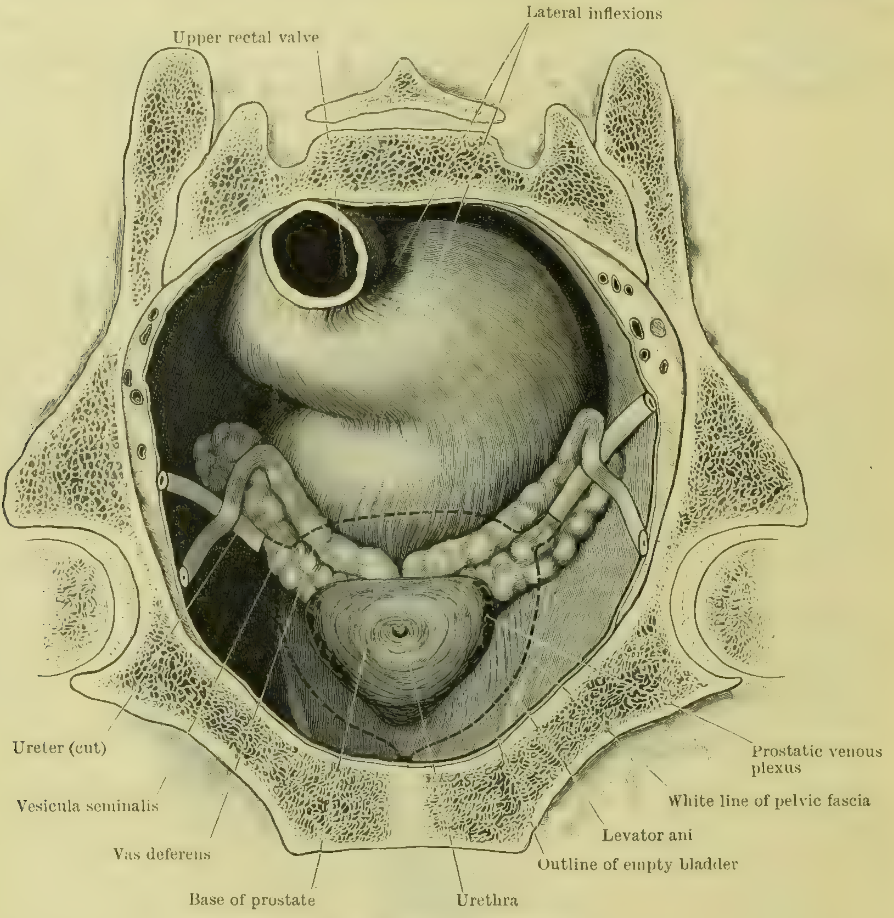


FIG. 702.—DISTENDED RECTUM IN SITU.

From a formalin-hardened male body, age 56. The peritoneum and extra peritoneal tissue have been removed, after sawing the pelvis along a plane passing through the upper part of the symphysis pubis in front and the lower part of the second sacral vertebra behind. The bladder, which was empty and contracted, has also been removed, but its form is shown by a dotted line. The rectum was very much distended, and almost completely occupied the pararectal fossæ.

crescentic shelves (Fig. 704), known as the **rectal valves**, which help to support the fæcal contents when the rectum is distended (Fig. 702).

This folding is maintained by the arrangement of the longitudinal muscular fibres, the majority of which are accumulated in the form of two wide bands, one on the front, the other on the back of the bowel. These two bands, which are continuous with, and comparable in their functions to, the tæniæ of the colon, are shorter than the other coats of the rectum; hence they give rise, as in the case of the colon, to a folding or sacculation of the tube, which can be effective only at the sides where the longitudinal fibres are fewest, for the front and back are occupied by the thickened longitudinal bands (see p. 1042).

In addition to supporting the fæces, these foldings greatly increase the capacity of the rectum without unduly dilating the tube. When the rectum is empty (Fig. 703) its course is comparatively straight, its lateral flexure being but slightly marked, and its whole calibre very much reduced.

In this condition it occupies only a small portion of the posterior division of the pelvic cavity near the mesial plane, and at each side, between it and the lateral wall of the pelvis, is a large fossa of the peritoneum (the pararectal fossa, p. 1051), which, when the bowel is empty, contains a mass of small intestine or pelvic colon (Figs. 701 and 703). When the rectum is distended the lateral flexures become much more marked, and the gut, projecting alternately to each side, passes out beneath the peritoneum, obliterating the pararectal fossæ (Fig. 702), and fills the greater part of the posterior division of the pelvis—a condition which could not be brought about with a straight rectum without an enormous increase in all the diameters of the tube.

According to Jonnesco, the rectum begins—that is, the pelvic mesocolon ceases—most frequently opposite the disc between the third and fourth sacral vertebræ. It is our experience that the mesocolon ends more frequently above than below the third sacral vertebra—often, indeed, at the level of the second.

At its upper end the rectum, following the curve of the sacrum, slopes downwards and at the same time slightly backwards; its middle portion is practically vertical, but the terminal third or more is directed downwards and forwards at an angle varying from 45° to 60° with the horizontal. The pelvic floor, upon which this latter part rests, forms here a similar angle with the horizontal. The bend which the bowel makes behind the lower end of the prostate, where the rectum passes into the anal canal, is, as pointed out above, abrupt, and usually approaches a right angle, so that the anal canal itself slopes downwards and backwards at an angle of nearly 45° with the horizontal.

Not uncommonly the abrupt curve, at the junction of the rectum with the anal canal, presents in front a knuckle-like projection (well seen on mesial section), immediately above the canal. It is most marked in females, and sometimes appears as if the bowel were doubled back upon itself at this point. The floor of the pouch thus formed may dip down in front, even below the level of the upper aperture of the anal canal (Fig. 744). This condition is most common in multiparæ, and is evidently due to the relaxed condition of the pelvic structures, and the slight support afforded by the perineal body to this part of the gut in these, and the great capacity and shallowness of the pelvis in the female.

In *length* the rectum usually measures about 5 or 6 inches (12·5 to 15·0 cm.), but it may be much longer.

Its *diameter* is smallest above, near the junction with the pelvic colon, and is greatest below, near the anal canal, where there is a special enlargement known as the **rectal ampulla** (ampulla recti). When empty the rectum measures little over an inch (2·5 cm.) in diameter, but in a state of extreme distension it may be as much as 3 inches (7·5 cm.) in width.

Peritoneal Relations of the Rectum (Figs. 703 and 749).—As a rule the upper two-thirds of the rectum has a partial covering of peritoneum—in front and at the sides at first, later on in front only—whilst the lower third has no peritoneal investment whatsoever. When the mesocolon ceases at the end of the pelvic colon, its two layers separate and leave the back of the rectum destitute of peritoneum. Very soon the membrane quits its sides also, and is then found on the front only; so that the greater part of the rectum lies behind or beneath the pelvic peritoneum, as it were, and is capable of expanding and contracting without being in any way hampered by its partial peritoneal coat.

From the front of the rectum the peritoneum is carried forwards to the base of the bladder in the male, forming the floor of the **recto-vesical** or **recto-genital pouch** (excavatio recto-vesicalis, Fig. 749). In the female it passes to the upper part of the posterior wall of the vagina, forming the floor of the **pouch of Douglas** (excavatio recto-uterina Douglasi, Fig. 744). Whilst at each side, in both sexes, it passes from the front of the rectum on to the posterior wall of the pelvis, forming the bottom of a large fossa, seen at the sides of the rectum when that bowel is empty, and known as the **pararectal fossa**. With distension this fossa is encroached upon by the enlarging bowel, and soon is obliterated.

The level at which the reflection of the peritoneum takes place from the front of the rectum is of considerable practical importance in connexion with operations in this region. As a general rule this reflection, that is the bottom of the recto-vesical pouch, is placed at a distance of 1 inch (2·5 cm.) above the base of the prostate, or about 3 inches above the anus, but the level is subject to considerable variation, being as a rule relatively much higher in well-developed muscular or fatty subjects, whilst it is usually lower in emaciated bodies, owing to the thinness of the structures forming the pelvic floor.

The bottom of the recto-vesical fossa may reach down in an extreme case to within an inch (2·5 cm.) of the anus, whilst it is not at all rare to find it within 2 inches (5·0 cm.) of that orifice;

on the other hand, it may be considerably higher than normal, sometimes being placed at a distance of 4 or 4½ inches (10·0 to 11·2 cm.) from the anus. It should also be added that the level is generally believed to be somewhat raised by distension of the rectum and bladder, and lowered by emptying these viscera, although this is denied by Jonnesco.

In the child at birth, the peritoneum extends down to the base of the prostate (Symington), and is thus lower in relation to the bladder; but this may be partly accounted for by the high position of this organ in the child.

As a rule it will be found that 2 inches (5·0 cm.) of the front of the rectum, exclusive of the anal canal, are entirely free from peritoneum, and it is this and the adjacent portion of the bowel which, being free from the restraining influence of the peritoneum, is most distensible, and is known as the **rectal ampulla.** Including the anal canal, 3½ inches (8·7 cm.) of the rectum, *measured along the front of the tube*, have no serous covering. On the other hand, the back is free from peritoneum for 5 or 6 inches (12·5 to 15·0 cm.)—or sometimes much more—above the anus.

It is also of interest to notice that the connexion of the peritoneum to the rectum varies in its character at different parts:—Above and in front it is closely adherent, and can be removed only with the greatest difficulty; at the sides and below the connexion is much looser. As a

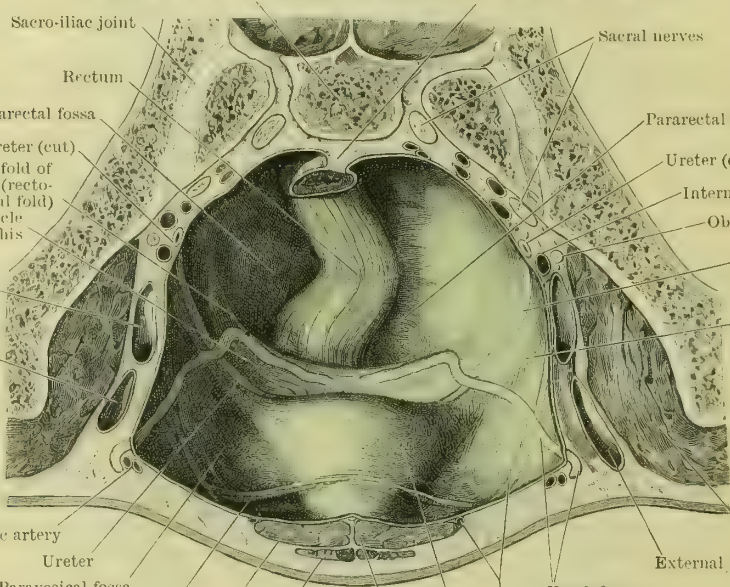


FIG. 703.—THE PERITONEUM OF THE PELVIC CAVITY.

The pelvis was sawn across obliquely in a thin male subject aged 60. Owing to the absence of fat the various pelvic organs were visible through the peritoneum, though not quite as distinctly as represented here. The bladder and rectum were both empty and contracted; the paravesical and pararectal fossa, as a result, were very well marked.

result, the peritoneum can be stripped off the rectum in its lower third or half without much difficulty, whilst in its upper portion this is not the case—an arrangement which admits of the free expansion of the rectal ampulla.

General Relations of the Rectum (Figs. 701 and 702).—*Behind*, the rectum rests on the front of the sacrum and coccyx, and below these upon the posterior part of the pelvic floor—here formed by the meeting of the two levatores ani in the ano-coccygeal raphe. When much distended it also comes into relation on each side with the lower part of the pyriformis and the sacral plexus. The bowel is separated from these structures by a very considerable amount of connective tissue, arranged (apparently in several layers) around the tube. In this tissue the two chief branches of the superior hæmorrhoidal vessels lie behind the upper part of the bowel, but lower down they are placed in relation to its sides.

At its sides above are the pararectal fossæ and their contents (pelvic colon, or ileum); below this the rectum is in contact with the coccygei and levatores ani

muscles, which run backwards to the coccyx on each side of the bowel. The branches of the superior hæmorrhoidal vessels are also found running down on its muscular coat, as far as the middle of the rectum, where they pierce the wall of the bowel.

In front, the rectum is separated from the bladder, to within an inch of the prostate, by the rectovesical pouch of peritoneum, which usually contains some coils of small intestine. Below the reflexion of the peritoneum the front of the bowel is in contact with the base of the bladder, the vasa deferentia, vesiculæ seminales, and the back of the prostate gland (Fig. 702), from all of which it is separated by the rectovesical layer of the pelvic fascia. *In the female* (Fig. 707) the rectum is separated from the posterior surface of the uterus and the upper end of the vagina by the pouch of Douglas and the intestine which it usually contains. Below the peritoneal reflexion it is in direct contact with the posterior vaginal wall, to which it is connected loosely above, but more closely below.

The lower portions of the rectum and bladder in the male are separated by the rectovesical fascia only, over a narrow triangular area which measures about an inch (2·5 cm.) in vertical height. The base of this triangle corresponds to the reflexion of the peritoneum from one organ to the other, and the apex to the base of the prostate, whilst the sides are formed by the vasa deferentia, which lie very close to one another except above, near the base of the triangle, where they diverge rather abruptly (Fig. 702). Through this triangle the operation of tapping the bladder from the rectum is performed.

The vesiculæ seminales, unless when of a small size, slope outwards and backwards round the front and sides of the distended rectum (Fig. 702), which they thus embrace, as it were, within their grasp.

The ureters, as they run inwards towards the base of the bladder, lie close in front of the vasa deferentia, and are not far separated from the distended rectum (see Fig. 702).

The portion of the rectum below the level of the peritoneal reflection is surrounded by the **rectal fascia**, a layer of connective tissue which is derived from the visceral layer of the pelvic fascia.

In the child the rectum, or at least its upper part, is relatively larger, and it pursues a much straighter course, than in the adult. As pointed out above, its peritoneal covering likewise descends lower at birth, and reaches as far as the base of the prostate.

THE ANAL CANAL.

Anal Canal (pars analis recti—third part of the rectum of the old descriptions).—In order to reach the exterior, it is necessary for the lower end of the bowel to pierce the floor of the pelvis. This it does by passing through the narrow interval left between the mesial borders of the levatores ani muscles (Fig. 701). As it passes between them, the two muscles pinch in the tube, and by the apposition of its lateral walls obliterate its cavity, reducing it to a mere slit-like passage. This passage, through which the rectum communicates with the exterior, is the "anal canal" (Symington).

Formerly this terminal portion of the tube was described as the "third part of the rectum," and, like the rest of that bowel, it was supposed to form a reservoir for the retention of the fæces. Symington pointed out that this was not the case. He showed that the canal was not of the same nature as the rest of the rectum, but that it was a mere passage through which the bowel discharged its contents, the relation between the two being practically the same as that between the urethra and the bladder in the female. It is probable, however, that, when the rectum is distended, the upper part of the anal canal is often, if not usually, occupied by the wedge-shaped lower end of the contained fæcal mass, whilst the chief bulk of the contents is supported by the rectal valves and the levatores ani.

The anal canal *begins* where the rectum proper terminates, namely, at the level of the levatores ani muscles, opposite the lower part of the prostate. When the distended rectum is cut across near its lower end, in a hardened body, and the cavity examined from the interior, a distinct projection, formed by the inner border of the levator ani (pubo-rectalis, or sphincter recti portion), is

seen on each side, indicating the upper limit of the canal. It is said that these ridges can also be felt during life by the finger introduced into the rectum (Cripps). Below, the anal canal *ends* at the anus, or anal orifice, by opening on the exterior.

Its *length* is usually from 1 to $1\frac{1}{2}$ inches (2·5 to 3·7 cm.), being greater when the bowel is empty, and less when it is distended. Its antero-posterior diameter when closed varies between $\frac{1}{2}$ and $\frac{3}{4}$ inch (12 to 19 mm.)

The *direction* of the anal canal, as already pointed out, is downwards and backwards, often forming an angle of nearly 45° with the horizontal, although it is usually somewhat nearer to the vertical.

Relations.—It is *surrounded* by both the external and internal sphincters, and above also by the borders of the levatores ani, these muscles forming a muscular cylinder around it (Fig. 701). *On each side* is situated the ischio-rectal fossa with its contained fat, which allows of the distension of the canal during the passage of fæces. *Behind* is placed a mass of mixed connective and muscular tissue, known as the **ano-coccygeal body** (Symington), which intervenes between it and the coccyx. Finally, *in front*, it lies close behind the bulb of the urethra and the base of the triangular ligament in the male, and a sound in the urethra can be easily felt by the finger introduced into the anal canal, particularly in thin bodies. In the female it is separated from the vagina by the wedge-shaped mass of fatty and muscular tissue known as the "perineal body."

Structure of the Rectum and Anal Canal.—The wall of the rectum is made up of four coats, viz.:—1. The **outer coat**, formed in part of peritoneum (already described), and, where the peritoneum is absent, of connective tissue which can be dissected off in several layers. In this connective tissue the hæmorrhoidal vessels run until they pierce the wall of the tube. In it also, at the back and sides of the rectum, are found embedded a number of rectal lymphatic glands.

2. The **muscular coat**, which is much thicker than in any other portion of the intestine, is composed of two stout layers of unstriped muscle—an outer longitudinal and an inner circular—like that of the intestine generally. The *longitudinal fibres*, although present all round, are chiefly accumulated on the front and back of the tube (see p. 1038), where they form two broad bands; at the sides they are reduced to a thin layer, the deepest fibres of which are folded in and take part in the formation of the rectal valves.

Where the rectum pierces the floor of the pelvis, the outer layer of longitudinal fibres is united to the deeper portion of the levator ani, partly by tendinous fibres and partly by an interchange of muscular fibres, between the levatores and the muscular coat of the rectum. This interchange of fibres, however, is denied by Peter Thompson and Browning. Below, the longitudinal fibres pass between the external and internal sphincter muscles, or through the latter to join the skin around the anus. The folding of the rectum from side to side, described above, is brought about and maintained by the shortness of the fibres of this coat on the front and back of the bowel.

In saggital sections of the pelvis near the mesial plane there can generally be seen a distinct band of red, longitudinally-arranged, muscular fibres, which descends on each side from the front of the coccyx to blend with the longitudinal fibres on the back of the rectum. This band is the **rectococcygeus muscle**. It is composed of striped fibres above, but becomes unstriped below.

Some unstriped muscular fibres which are found descending in the subcutaneous tissue of the lower part of the anal canal, to join the skin around the anus, have been described by Ellis as the **corrugator cutis ani**. According to Roux, they are some of the longitudinal fibres of the rectum which have passed through the internal sphincter to the submucous tissue, and then descended to the skin.

The *circular fibres* form along the whole length of the tube a continuous layer, which is doubled inwards to assist in the formation of each rectal valve, and is thickened below to form the internal sphincter of the anus. The **internal sphincter** (sphincter ani internus), as just pointed out, is formed by a great, and rather sudden, increase of the circular muscular fibres, which begins at the upper end of the anal canal. It surrounds the canal for about an inch (2·5 to 3·0 cm.), and terminates $\frac{1}{4}$ or $\frac{1}{3}$ inch (6 or 7 mm.) above its lower aperture (Fig. 705).

3. The **submucous coat** is composed of loose areolar tissue, which allows of a free movement of the mucous layer on the muscular coat, and which also admits, under certain abnormal conditions, of a prolapse of the mucous membrane through the anal orifice. The hæmorrhoidal plexus of veins is contained in this layer.

4. The **mucous coat** must be considered separately in the rectum and anal canal. That of the rectum is redder in colour than the mucous membrane of the colon, as a result

of its greater vascularity. It is also thicker, and owing to the looseness of the underlying submucosa, is thrown into numerous irregular rugæ when the rectum is empty; these disappear when the bowel is distended, and there then become evident three (sometimes more, sometimes less) crescentic folds, which are much less noticeable in the empty state, and which have been already referred to as the rectal valves. Lymphoid nodules and glands of Lieberkühn are present; but these latter are not so numerous as in the colon, although their calibre is greater.

The *mucous membrane of the anal canal* presents in its upper half a number of vertical ridges known as the *columns of Morgagni;* between the lower ends of these are found a series of small semilunar folds which are disposed horizontally around the passage and are called the *anal valves* (Fig. 705). Above the level of the anal valves the canal is lined by a modified mucous membrane resembling that of the rectum; the portion below the valves (*i.e.* the lower 12 to 16 mm. of the canal) is covered by modified skin, continuous with that around the anus.

The mucous membrane of the rectum presents a characteristic punctated appearance, which is due to the presence of a considerable number of rounded depressions, such as might be made by firmly pressing a finely-pointed pencil against the membrane. These *rectal pits*, of which we can find no previous description, are tubular in form, and have an accumulation of lymphoid tissue at the bottom of each; the whole appearance being such as might be produced if a small solitary gland were drawn down from the surface into the intestinal wall.

Rectal Valves, or Valves of Houston (plicæ transversales recti).—These, sometimes termed the valves of Kohlrausch, are crescentic shelf-like folds which project into the cavity of the rectum on its lateral aspects (Fig. 704). They are composed of an infolding of the mucous, submucous, and greater part of the muscular coats, and their form is preserved by the relative shortness of the anterior and posterior bands of longitudinal muscular fibres. They are produced, as pointed out above, by the projection, into the interior of the bowel, of the creases on the exterior which result from the lateral inflections of the rectum. In the majority of cases three are present (there may be four, five, or, it is said, even more), but often the lowest of the three is small or absent; or all the valves may be ill-developed and indistinct. When mesial sections of the *empty* rectum are examined, the valves are not easily seen (Fig. 737), as they then project but slightly, and are almost completely hidden amongst the numerous rugæ of the mucous coat. They are most evident in a distended rectum which has been hardened *in situ;* they can also be seen during life, *per anum*, with the aid of a rectal speculum.

Fig. 704.—Diagram of Rectum, showing Houston's valves in interior.

The diagram is a reduced tracing of Fig. 702. After removal of the prostate, etc., an aperture was made in the anterior wall of the rectum, through which two rectal valves can be seen corresponding to lateral inflections on the exterior. The levator ani is also shown, and its relation to the beginning of the anal canal is suggested.

As a rule two valves are found on the left and one on the right side; this latter is generally the largest, and is situated a little above the level of the peritoneal reflection, viz. 3 or $3\frac{1}{2}$ inches (7·5 to 8·7 cm.) above the anus; the other two valves are found about 1 to $1\frac{1}{2}$ inches (2·5 to 3·7 cm.) higher up and lower down respectively. The valves are distinctly marked in the fœtus (see Fig. 705), and seem to constitute an essential part of the human rectum, their use being to support the contents of the rectum, which they break up into segments, each supported by a valve (see p. 1038). They are said to interfere sometimes with the introduction of an enema tube.

The rectum in animals generally is free from the lateral inflexions described above, and the condition found in man is evidently an adaptation to the erect attitude. In quadrupeds the contents of the rectum do not press unduly on the sphincter, owing to the horizontal position of the body. With the assumption of the erect attitude, on the other hand, the whole weight of the contents would be thrown on the sphincters, were it not for the lateral foldings and the resulting shelves.

Columns of Morgagni (columnæ recti Morgagni).—The mucous membrane of the anal canal presents, in its upper, and part of its middle thirds, a number (5 to 10) of *permanent* vertical folds, separated by grooves, and known as the columns of Morgagni (Fig. 705). They are usually $\frac{1}{3}$ to $\frac{1}{2}$ inch (8 to 12 mm.) in length, $\frac{1}{8}$ to $\frac{1}{4}$ inch (3 to 6 mm.) in width, and they extend down to within $\frac{1}{2}$ or $\frac{2}{3}$ inch (12 to 7 mm.) of the anal aperture. They are formed by infoldings of the mucous membrane, containing in their interior some unstriped muscle derived from the muscularis mucosæ, and also, as a rule, an artery and a vein.

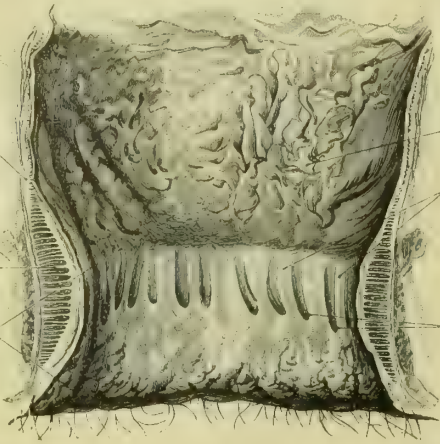


Fig. 705.—The Interior of the Anal Canal and Lower Part of Rectum,

Showing the columns of Morgagni and the anal valves between their lower ends. The columns were more numerous in this specimen than usual.

Very often the contained vein presents an enlargement, or a knob-like tortuous plexus in the lower part of the column; below this the plexus is continued down beneath the mucous membrane of the lower zone of the anal canal into the anal veins (see page 1045). This portion has accordingly been described as the hæmorrhoidal zone of the anal canal. Sometimes the columns of Morgagni are very indistinct; occasionally no trace of them can be found, although in the fœtus (Fig. 706) they are usually well marked.

Anal Valves (of Morgagni).—If a probe be passed downwards along the groove which separates two adjacent columns of Morgagni (Fig. 705), its point will usually catch in a small crescentic fold which joins the lower ends of the two columns. These little folds, which resemble in miniature the segments of the semilunar valves of the heart, are the anal valves. They project inwards and upwards, and behind each is found a little pocket-like **sinus** (sinus rectalis).

These valves were first described by Morgagni. Recently the view has been advanced by Ball that they are the remains of the embryonic cloacal or anal membrane; and he explains the production of "painful fissure of the anus" by the tearing down of one of them during defæcation by hardened masses of fæces.

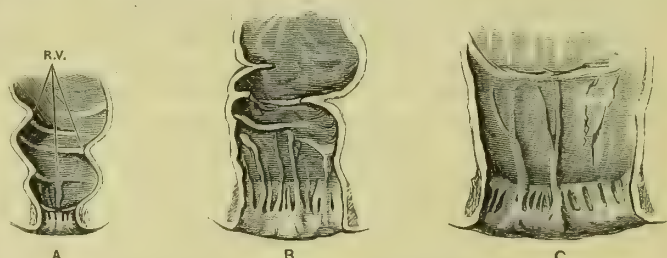


Fig. 706.—The Anal Canal and Lower Part of Rectum in the Fœtus.

A, aged 4 to 5 months; B, 6 months; and C, 9 months. In each the anal canal is distinctly marked off from the rectum proper; the columns of Morgagni and the rectal valves are distinct. R.V. Rectal valves.

The epidermis is continued in a thin and modified form from the exterior up along the anal canal as far as the margins of the anal valves; and the view is pretty generally held that only this lower portion of the anal passage is formed from the proctodæum in the embryo. The junction of the skin with the mucous membrane is indicated by a fine wavy line ("white line" of Hilton—ano-cutaneous line of Hermann) which runs around the bowel at the level of the valves. The mucous membrane of the region immediately above the anal valves is of a more or less transitional nature; glands are absent from it, and over the columns of Morgagni it is said to be covered with stratified epithelium, the superficial cells of which are flattened, whilst in the grooves between the columns the epithelium is columnar. In the upper zone of the anal canal the mucous membrane gradually approaches to the rectal type, but the Lieberkühn's glands and lymphoid nodules are few and scattered.

Anus or Anal Orifice.—At the inferior aperture of the anal canal, the

modified skin of its lower zone passes into the ordinary skin. A little way outside the orifice, hairs, sebaceous glands, and large modified sweat-glands (glandulæ circumanales) appear.

Action of the Sphincters.—In connection with the anal canal are found three muscles—namely, the paired levatores ani, the external sphincter, and the internal sphincter—the action of which should be briefly referred to here.

Levator Ani.—The fibres of the levator which arise from the pubis (pubo-coccygeus or sphincter recti portion) pass backwards on each side of the beginning of the anal canal, and, in great part, meet behind the passage. These two muscular bands—which are but a little distance apart at their origin, and are actually united behind the bowel—are closely approximated during the contraction of the muscles, like the limbs of a clamp, and, pressing on the sides of the anal canal, they assist in closing the upper part of that passage, whilst at the same time drawing it slightly towards the pubes. There is little doubt that the levator ani in this way acts as one of the chief sphincters of the bowel; and it should be noticed that it is placed where its action would be most effective, namely, opposite the point at which the rectum is narrowed or "pinched in" to form the anal canal. In addition to its sphincter action the muscle supports the expanded bowel immediately above the anal canal, and in this way sustains the weight of the fæces when the rectum is distended. It is probably relaxed during defæcation, except perhaps at the completion of the act. The muscle is under the control of the will.

The **external sphincter** forms a muscular cylinder around the lower two-thirds of the anal canal, with (except in the case of some of its inner fibres) an anterior and a posterior attachment. When the muscle contracts, its fibres are tightly stretched between its two attachments, and the space between them is reduced to a narrow antero-posterior slit. By this action the anal canal is flattened from side to side and closed, so that, whilst the levator ani is the sphincter of the upper aperture of the anal canal, the external sphincter closes its lower and greater part. It is under the control of the will, but under ordinary circumstances it is in a state of tonic contraction.

The **internal sphincter** is merely a thickening of the circular muscular coat at the lower end of the bowel. It is continuous with the circular fibres of the gut, not only in structure, but probably also in action, its chief use being to empty the anal canal completely, after the passage of each fæcal mass. Owing to the fact that the canal is an antero-posterior slit, not a circular orifice, and that the internal sphincter forms a muscular ring around it, acting alone, it is scarcely competent to keep the sides of the canal in apposition, and probably it acts rather as a detrusor than a true sphincter of the anal passage.

Vessels.—The rectum and anal canal receive their blood supply from three chief sources, namely, the three hæmorrhoidal arteries; to these another less important, though constant, source may be added—the middle sacral artery.

1. The **superior hæmorrhoidal**, the principal artery of the rectum, is the prolongation of the inferior mesenteric trunk (Fig. 566, p. 795). At first it descends in the root of the pelvic mesocolon until the rectum is reached. Here it divides into two chief branches which run downwards and forwards around the sides of the rectum—the right, usually the larger, lying more behind, the left more to the front, and the two, as it were, embracing the bowel between them (Fig. 701). From these two arteries come off secondary branches (about five to eight in all), which pierce the muscular coat about the middle of the rectum, and then descend in the submucosa as a series of longitudinally-running "terminal branches" as far as the anal valves, above the level of which one is usually found beneath each column of Morgagni. These terminal branches give off numerous twigs in their course, which form a hæmorrhoidal plexus in the submucosa by anastomosing with one another, and also with branches of the middle, and, in the lower part of the bowel, of the inferior hæmorrhoidal artery.

2. The **middle hæmorrhoidal arteries**, two in number—one on each side—are usually branches of the anterior division of the internal iliacs; they run down on the side wall of the lower part of the rectum, and after giving off branches to the bladder, seminal vesicles, prostate (or vagina, according to the sex), each breaks up into four or five small branches, some of which supply the muscular wall of the lower part of the rectum, whilst the others pierce the muscular coat near the upper end of the anal canal, and join in the submucosa with the plexus formed by the superior hæmorrhoidal artery already described.

3. The **inferior hæmorrhoidal arteries**, generally two or three in number on each side, arise at variable levels from the internal pudic arteries, whilst these latter are situated on the outer side of the ischio-rectal fossæ. They pass inwards and downwards through the fat in the fossæ, and, near the wall of the anal canal, break up into branches, some of which are distributed to the levatores ani and the sphincters, whilst others pierce the sphincters and break up in the submucosa into a close network which supplies the lower part of the anal canal, and communicates above with the plexus formed by the superior and middle hæmorrhoidal arteries. The inferior hæmorrhoidal artery is distributed chiefly on the back, and the middle hæmorrhoidal chiefly on the front of the lower part of the bowel.

4. One or more small branches of the **middle sacral artery** reach the back of the rectum, where they are distributed chiefly, if not solely, to the muscular coat.

Anastomosis of the Hæmorrhoidal Arteries.—The superior and middle hæmorrhoidal arteries anastomose freely, not only in the hæmorrhoidal plexus of the submucosa, but also, as a rule, by a few large branches on the exterior of the bowel: some perforating branches of the middle sacral also join the plexus in the submucous layer at the lower part of the rectum, as do numerous small branches from the inferior hæmorrhoidal arteries which pierce the sphincters. In addition,

small branches of these several arteries unite with one another in the muscular coat. It should be remarked that the superior hæmorrhoidal artery supplies both the muscular and mucous coats above, whilst it is confined to the latter in the lower few inches of the gut, the muscular coats here being supplied by the middle and inferior hæmorrhoidal vessels.

Veins of the Rectum and Anus.—These form two chief plexuses of large vessels devoid of valves, namely, the internal hæmorrhoidal plexus situated in the submucous coat, and the external hæmorrhoidal plexus in the outer coat. The **internal hæmorrhoidal plexus** takes origin near the margin of the anus in a number of small (anal) veins, which are radially disposed beneath the skin of the anus, and communicate below with the rootlets of the inferior hæmorrhoidal vein over the external sphincter. These **anal veins**, traced upwards, join together, and are joined by others from the surrounding parts to form larger and often tortuous vessels, which ascend in the columns of Morgagni, where they frequently present ampullary enlargements, varying in size up to that of a small pea, which are said to be the starting-points of hæmorrhoids. Passing upwards, the veins are known as the "terminal veins"; they communicate freely with one another, forming the plexus, and unite into still larger vessels, which pierce the muscular coat about the middle of the rectum, and join the two branches of the superior hæmorrhoidal vein.

From the lower part of the internal hæmorrhoidal plexus numerous vessels pass through the external sphincter to join a venous network on the outer surface of that muscle, from which the **inferior hæmorrhoidal veins** arise. This network, as pointed out above, also communicates with the internal hæmorrhoidal plexus, through the anal veins which descend from the latter beneath the skin of the anal canal, to the exterior of the sphincter.

The various veins which pass out through the walls of the rectum unite freely on its exterior to form a rich venous plexus (**external hæmorrhoidal plexus**), through which the three hæmorrhoidal vessels are brought into free communication with one another. Passing off from this plexus, the **superior hæmorrhoidal vein** joins the inferior mesenteric, which opens into the portal vein; the middle hæmorrhoidal joins the internal iliac, a tributary of the vena cava; and the inferior hæmorrhoidal joins the internal pudic, a tributary of the internal iliac. Thus, on the rectum, a free anastomosis is established between the veins of the portal and systemic circulations.

Lymphatics.—Most of the lymphatics of the rectum join a number (four or five) of rectal glands found in the connective tissue coat of the bowel along the superior hæmorrhoidal vein and its two branches, whence they pass to the sacral glands on the front of the sacrum. Some of those from the lower part of the anal canal join the cutaneous lymphatics round the anus, and pass with them to the oblique set of superficial inguinal glands. A few of the lymphatics from the lower portion of the rectum are said (by Quenu) to join the internal iliac glands, but these are inconstant according to Gerota.

Nerves.—The nerves of the rectum come partly from the sympathetic and partly from the cerebro-spinal system. The sympathetic fibres are derived on the one hand from the inferior mesenteric plexus, and on the other from the right and left divisions of the hypogastric plexus (*i.e.* the pelvic plexuses), the former accompanying the superior hæmorrhoidal, the latter the middle hæmorrhoidal vessels, to the rectum. The cerebro-spinal fibres arise from the second, third, and fourth sacral nerves soon after these leave the sacral foramina (and constitute the "pelvic splanchnics" of Gaskell). They run forward in the pelvic connective tissue, and joining the pelvic plexuses, reach the side of the rectum. Fibres of the inferior hæmorrhoidal branch of the internal pudic nerve (third and fourth sacral) are also distributed to the lower part of the anal canal as well as to the external sphincter.

It has been shown by experiments on animals, that the cerebro-spinal nerves (from the second, third, and fourth sacral) convey motor impulses to the longitudinal fibres, but inhibitory impulses to the circular muscular fibres. In like manner the branches from the sympathetic convey motor fibres (derived from some of the lumbar rami communicantes) to the circular muscle, and inhibitory fibres to the longitudinal muscle of the rectum.

The reflex centre which governs the action of the sphincters and the muscular fibres of the rectum ("defæcation centre") is situated in the lumbar region of the cord, and appears to be capable of carrying out the whole act of defæcation even when separated from the brain.

Variations.—The best known anomalies found in connexion with the rectum are those classed under the term **imperforate anus** or **atresia ani**. The atresia may be simply due to a partial or complete persistence of the anal membrane (see p. 43), which separates the proctodæum from the hind-gut in the embryo (artresia ani simplex); or the hind-gut may be deficient in its lower part, when there is a considerable interval between the proctodæum and the gut (defectus recti partialis, vel totalis); or the rectum may open into the vagina, the uterus, the bladder, or the ureters, when usually no anus is evident; or finally the cloaca may persist. Other forms are also described, but the foregoing are those most commonly found.

For the **development** of the rectum and anus, see pp. 32 and 43.

THE PERITONEUM.

An introductory sketch of the peritoneum was given on p. 997; subsequently, when describing the abdominal viscera, an account of its detailed relations to each of these was included. We shall here consider the membrane and its folds as parts of one continuous whole; and we shall also describe its arrangement as seen

on horizontal and vertical sections of the abdomen—a favourite method of studying the peritoneum.

As already explained, the peritoneum is the serous membrane which, on the one hand, lines the abdominal cavity, and on the other forms a more or less complete covering for the contained viscera. The portion which lines the walls of the cavity is known as the **parietal peritoneum** (peritoneum parietale), that which clothes the viscera as the **visceral peritoneum** (peritoneum viscerale). The membrane is connected to both walls and viscera by a layer of areolar tissue—the extra or subperitoneal connective tissue—which is considerable in amount in certain regions, whilst it is reduced to a mere trace in others, particularly on the viscera. (The subperitoneal tissue is described at p. 995.)

The peritoneum is described as consisting of **two sacs**—a greater and a lesser. The former lines the greater portion of the abdominal cavity, and invests most of the abdominal viscera; the latter lies chiefly behind the stomach, and is much more restricted in its distribution. It must be clearly understood that these two sacs are not two separate cavities, but simply subdivisions of one great cavity; for the lesser is merely a recess of the greater sac, from which it has become partly shut off by changes that take place in the position of the adjacent viscera during their development. If the great sac be compared to a bag, the lesser sac might be represented as a pocket lying behind, and opening into it by a narrow orifice—the foramen of Winslow—on its posterior wall.

Speaking generally, the great sac lines the walls of the abdominal cavity, and it also covers the various organs which receive a peritoneal investment, except the back of the stomach, the Spigelian and caudate lobes of the liver, the left suprarenal capsule, the upper surface of the pancreas, and also parts of the spleen, left kidney, and transverse colon; all of which, as well as the parietes behind the Spigelian lobe, are clothed by the small sac.

The **great sac of the peritoneum** is placed between the parietes in front and the abdominal viscera behind. It is composed of two layers, an anterior which lines the anterior abdominal wall, and a posterior which covers the viscera; but this posterior layer is carried forwards by the viscera, so that the two layers come in contact, and the cavity of the sac is practically obliterated.

The **anterior layer of the great sac** covers the anterior abdominal wall completely, from the diaphragm above to the pelvis below. Over the greater part of its extent the connection of the peritoneum to the wall is by a small amount of fatty extra-peritoneal connective tissue; but below, near the pubic region, the fat is more abundant, and the connection between the two becomes much looser. This is to allow of the peeling off of the peritoneum, which takes place here during distension of the bladder. As the bladder enlarges it passes up along the anterior abdominal wall, off which it strips the peritoneum, so that, in the fully distended condition, it may be in contact with this wall, without the interposition of peritoneum, for a distance of two inches (5·0 cm., or occasionally more) above the pubes (Fig. 738).

Running up in this fatty tissue are found five cord-like structures, one placed in the middle line, and two at each side. These are (*a*) the **urachus**—the remains of the allantois of the fœtus—which in the adult is a slender fibrous band connected to the umbilicus above, and to the apex of the bladder below, where it usually becomes much stouter. External to the urachus, and some distance from it (Fig. 703), will be found, in the same fatty tissue, (*b*) two stouter fibrous cords, the **obliterated hypogastric arteries** (arteriæ umbilicales). Traced upwards, these also become more slender, and approach the urachus, along with which they are connected to the umbilicus. Below, they grow thicker, and can be followed backwards along the side wall of the pelvis to the internal iliac arteries, which they join. (*c*) Further out still, the **deep epigastric arteries** are seen running upwards and inwards from the external iliac trunk on each side.

When the anterior abdominal wall is examined from behind, it will be seen that these five structures which lie on the front of the peritoneum carry that membrane inwards towards the abdominal cavity in the form of five more or less

distinct ridges, in relation to which are found on each side three peritoneal fossæ, known as the **inguinal pouches** or **fossæ** (fovea inguinales).

The **external inguinal fossa** (fovea inguinalis lateralis) lies outside the deep epigastric artery, and corresponds to the position of the internal abdominal ring. At its bottom is often found a dimple-like depression of the peritoneum, indicating the point from which the processus vaginalis passed down, in connexion with the descent of the testicle. The **middle inguinal fossa** (fovea inguinalis mesialis) is situated between the deep epigastric and the obliterated hypogastric arteries; whilst the **internal inguinal fossa** (fovea inguinalis interna, fovea supravesicalis) lies to the inner side of the obliterated hypogastric artery, namely, between it externally and the urachus internally. Seeing that the obliterated hypogastric artery, in passing upwards, crosses Hasselbach's triangle, dividing it into an outer and an inner part, it follows that the middle inguinal fossa corresponds to the outer division of the triangle, and the inner fossa to its inner division.

Still another fossa of the peritoneum is seen in this region, just beneath the inner part of Poupart's ligament, corresponding to the position of the femoral or crural ring, and consequently known as the **femoral** or **crural fossa** (fovea femoralis). It may be added that the vas deferens crosses the outer part of this latter fossa, and the obliterated hypogastric artery its inner part. The significance of these fossæ is pointed out in connection with the applied anatomy of the inguinal and femoral regions.

Near the middle line, above the umbilicus, the peritoneum is carried back from the anterior abdominal wall and diaphragm to the parietal surface of the liver in the form of a crescentic fold, the **falciform ligament** of the liver (ligamentum falciforme hepatis, described with the liver), which connects the liver to the abdominal wall. This fold lies somewhat to the right of the middle line, and extends almost as low down as the umbilicus. It consists of two layers of peritoneum, between which, in the lower border of the fold, runs the round ligament of the liver—the remains of the umbilical vein of the fœtus.

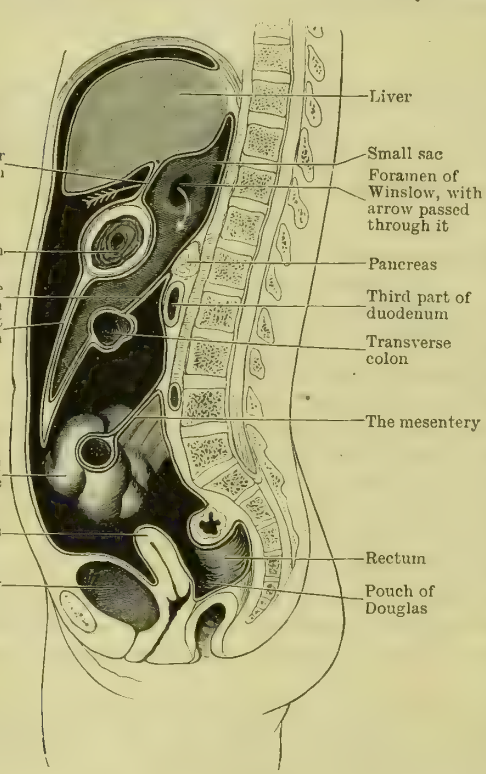


Fig. 707.—Diagrammatic Mesial Section of Female Body, to show the peritoneum on vertical tracing. The great sac of the peritoneum is black and is represented as being much larger than in nature; the small sac is very darkly shaded; the peritoneum in section is shown as a white line: and a white arrow is passed through the foramen of Winslow from the great, into the small sac.

Posterior Layer of the Great Sac.—After clothing the anterior abdominal wall, in the manner just described, the anterior layer of the great sac is continued back on the under surface of the diaphragm, until this latter begins to descend behind the liver, when it is reflected from the diaphragm on to the upper aspect of the liver, and here the anterior passes into the posterior layer of the great sac. The posterior layer first clothes the upper aspect of the liver, then turns round its anterior border, and is continued back on the under surface as far as the attachment of the lesser omentum, where it quits the liver and passes down, as the anterior layer of the lesser omentum, to the lesser curvature of the stomach.

The line of reflexion from diaphragm to liver is interrupted near the mesial plane by the falciform ligament. The portion lying to the right of this fold forms the upper layer of the coronary ligament; that to the left of it, the upper layer of the left lateral ligament of the liver.

The extent to which the peritoneum of the great sac passes back on the under surface of the

liver varies according as it is traced at the right, the left, or the middle portion of the liver. It clothes the right portion as far back as the lower edge of the uncovered area of the liver, where it is reflected on to the posterior wall of the abdomen and the top of the right kidney (constituting the hepato-renal ligament), as the lower layer of the coronary ligament. On the left portion it is continued back as far as the posterior border of the left lobe—or even a little way on to its upper surface—whence it passes to the diaphragm as the inferior layer of the left lateral ligament. The middle region of the under surface it clothes only as far as the portal fissure and the fissure of the ductus venosus; from these the peritoneum is carried down as the anterior layer of the lesser omentum to the lesser curvature of the stomach, where we shall return to it directly.

The peritoneum, which passes back on the under surface of the diaphragm to the left of the liver, is continued down on the posterior abdominal wall, behind the fundus of the stomach and the spleen, until the left kidney is reached. It covers the upper and outer part of the kidney, and is then carried forward as the **lieno-renal ligament** to the spleen, around which it passes —clothing its renal, phrenic, and gastric surfaces—as far as the hilus (Fig. 709); from this it is carried to the stomach as the anterior layer of the **gastro-splenic omentum**. Similarly, the under layer of the left lateral ligament is continued down on the back part of the diaphragm to the œsophagus, the anterior and left sides of which it clothes. It also forms a little fold at the left of the œsophagus, known as the **gastro-phrenic ligament** (see p. 1007 and Fig. 710).

At the right side, the portion of the peritoneum which forms the under layer of the coronary ligament is carried down over the right kidney (and lower part of the suprarenal capsule) to the duodenum and hepatic flexure, over both of which it passes.

We shall now follow down the posterior layer of the great sac—which we have already traced to the stomach—as seen in a sagittal section (Fig. 707).

Having reached the lesser curvature of the stomach, it passes down over the front of that organ, clothing it completely as far as the great curvature. From this it descends, in front of the transverse colon and small intestine, forming the anterior layer of the great omentum—a large apron-like fold, containing the lower part of the small sac in its interior, which hangs down from the stomach. Arrived at the lower border of the great omentum, the membrane returns on itself, and passes upwards towards the posterior abdominal wall, forming the posterior layer of that omentum. On the way it meets, and passes behind the transverse colon, clothing its posterior aspect at the same time (Fig. 707), and is then continued, as the posterior layer of the transverse mesocolon, up to the posterior abdominal wall, which it reaches at the anterior border of the pancreas (Fig. 707).

From the anterior border of the pancreas it is continued downwards again, clothing first the lower part of that organ, then the front of the third portion of the duodenum, and below this the posterior abdominal wall. From this latter, however, it is soon carried forwards again by the branches of the superior mesenteric vessels, passing to the small intestine. Running out along these, it forms the upper (or more correctly, the right) layer of the obliquely-placed mesentery (Fig. 707): on reaching the small bowel at the border of the mesentery, it invests that tube, giving it its serous coat, and then returns—as the under, or left, layer of the mesentery—to the posterior abdominal wall, on which it runs down, covering the great vessels near the middle line, and the psoas muscles and ureters at each side, to enter the pelvis. The mesentery is described at page 1020.

Pelvic Peritoneum.—The detailed arrangement of the peritoneum in the pelvic cavity is somewhat complicated, and is fully described in connexion with the several pelvic organs. A general account will suffice here.

Having passed over the brim all round, it enters the pelvis, and covers its walls as low as the pelvic floor, across which it passes to the various organs. Behind, it invests completely, and forms a mesentery (pelvic mesocolon) for, the pelvic colon, as far down as the third sacral vertebra. Here the colon joins the rectum proper, and the complete investment of the bowel ceases.

As the end of the pelvic colon is approached the two layers of its mesocolon become shorter, and when the rectum is reached, they separate, leaving its posterior surface uncovered, whilst the bowel is clothed in front and at the sides. Lower down, the membrane leaves the sides, and finally, at a point which is usually about 3 inches (7·5 cm., see page 1039) above the anus, it leaves the front of the bowel, and in the male is carried on to the back part of the bladder (here covered by the seminal vesicles and vasa deferentia), forming the floor of the **recto-vesicle pouch** (excavatio recto-vesicalis, recto-genital pouch) found between these organs. It then covers the upper surface of the bladder, and passing off from its sides to the

walls of the pelvis, constitutes the so-called **false ligaments** of that organ. From the apex of the bladder it is carried on to the anterior abdominal wall by the urachus, thus forming the **superior** or **anterior false ligament** of the bladder (plica pubovesicalis).

In the female (Fig. 707), the peritoneum, on leaving the rectum, passes to the posterior wall of the vagina, the upper portion of which it covers. From this it is continued up over the posterior surface and fundus of the uterus, and down on its anterior surface as far as the junction of the cervix and body (Fig. 775). Here it passes from the uterus to the bladder, which it partly covers, as in the male, and is then carried on to the anterior abdominal wall. Between the rectum behind, and the uterus and vagina in front, is situated the **pouch of Douglas** (excavatio rectouterina Douglasi, recto-genital pouch), the entrance of which is limited on each side by a fold passing from the cervix of the uterus around the sides of the

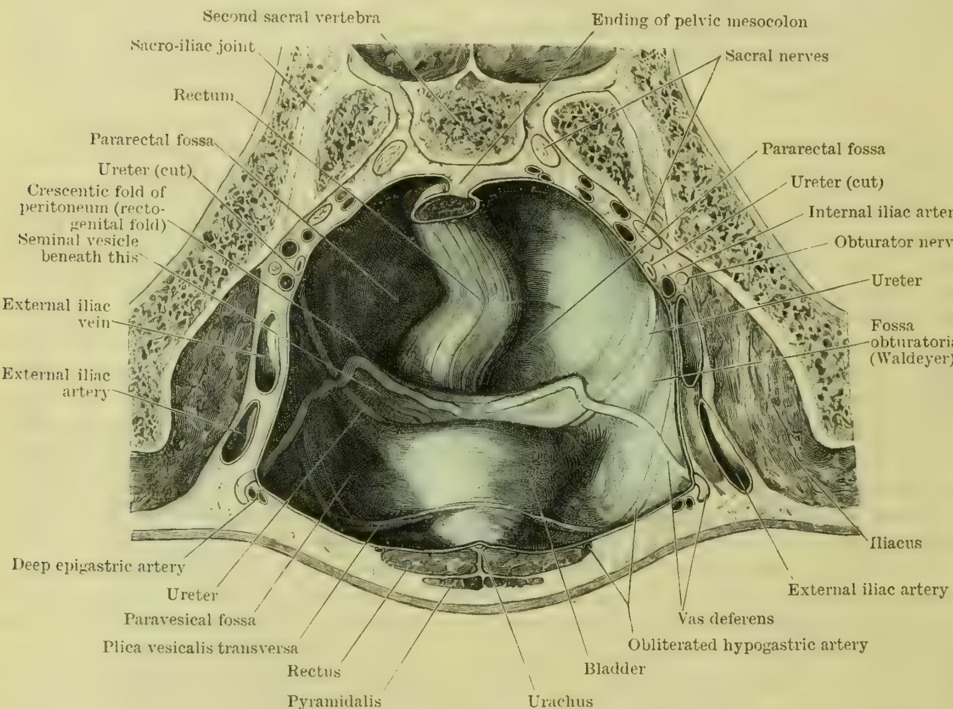


FIG. 708.—THE PERITONEUM OF THE PELVIC CAVITY.

The pelvis was sawn across obliquely (as in Fig. 702) in a thin male subject aged 60. Owing to the absence of fat the various pelvic organs were visible through the peritoneum, though not quite so distinctly as represented here. The bladder and rectum were both empty and contracted; the paravesical and pararectal fossæ as a result were very well marked.

pouch towards the rectum; these are the **folds of Douglas** (plicæ rectouterinæ Douglasi, recto-genital folds), and they contain in their interior the **utero-sacral ligaments** (musculi recto-uterini), two bands of fibrous tissue with plain muscle fibres intermixed, which pass from the cervix of the uterus, backwards on each side of the rectum, to blend with the connective tissue on the front of the lower part of the sacrum.

Similarly, in front of the uterus, between it and the bladder, is found the much smaller **utero-vesical pouch** (excavatio vesico-uterina). Finally, the peritoneum is prolonged as a wide fold from each margin of the uterus to the side wall of the pelvis, constituting the **broad ligament** of the uterus (ligamentum latum uteri), within which are contained the Fallopian tube, the ovary, the round ligament, and other structures (see p. 1130).

When the bladder is empty, there is seen at each side, between it and the pelvic wall, a considerable peritoneal depression—the **paravesical fossa** (Fig. 708). This fossa is traversed by a peritoneal fold—the plica vesicalis transversa—which is found running transversely outwards

from the upper surface of the empty bladder, and when well marked, passing to the neighbourhood of the internal abdominal ring.

Above the bladder, on each side of the urachus, is found the **internal inguinal fossa** already referred to (p. 1048). Both of these fossæ are practically obliterated by distension of the bladder.

Similarly, there is seen at each side of the empty rectum, on the posterior pelvic wall, a large depression, which may be known as the **pararectal fossa** (fossa pararectalis, Fig. 708). When the rectum is empty and contracted, these fossæ are filled by intestine; during distension, the rectum increasing in width, expels the intestine and practically obliterates the fossæ.

Transverse Tracing of the Peritoneum.—If the peritoneum be followed transversely around the abdomen, just above the level of the iliac crest, where the complications produced by the small sac are absent (Fig. 709, B), few difficulties will be encountered. From the anterior abdominal wall it passes round on each side to the back, lining the lateral and posterior walls. Passing inwards on the posterior wall, it meets the colon—ascending on the right side, descending on the left—over which it is carried, in each case covering the bowel in front and at the sides only, and leaving the posterior surface bare, as a rule. Sometimes, however, the covering is complete, and a short mesentery is formed. It is next continued inwards over the psoas muscles, the ureters, and the great vessels, on the front of which it meets the superior mesenteric artery and vein running downwards to the intestines. From both sides it passes forwards on these vessels, forming the right and left layers of the mesentery; and finally, having reached the intestine, it clothes it completely, and the two portions become continuous on the bowel.

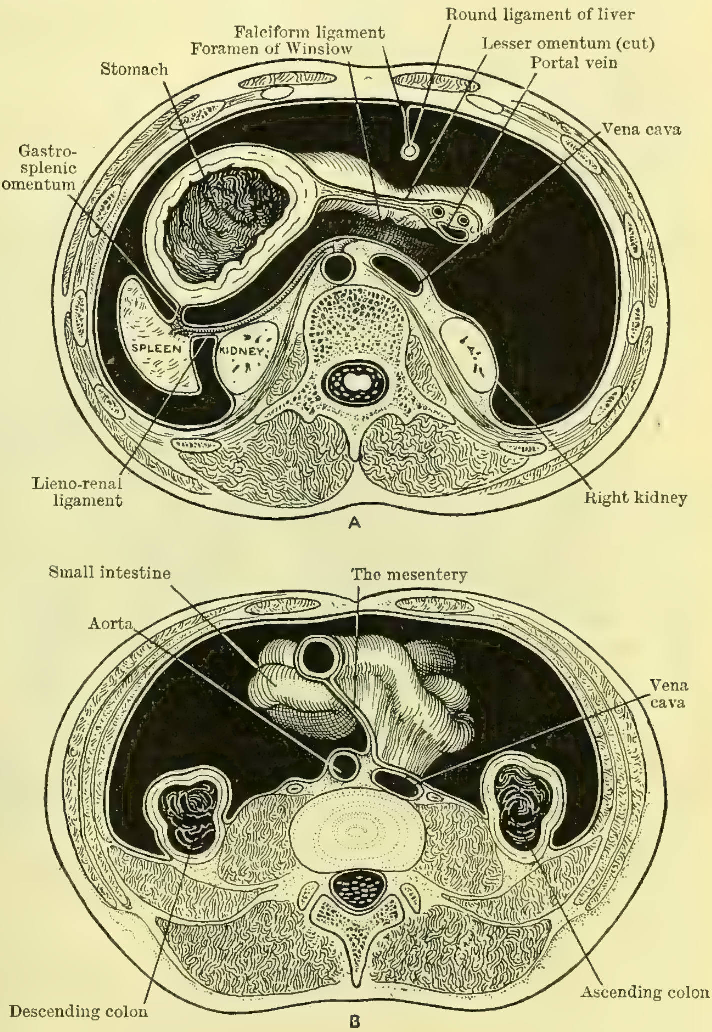


FIG. 709.—DIAGRAMMATIC TRANSVERSE SECTIONS OF ABDOMEN, to show the peritoneum on transverse tracing. A, at level of foramen of Winslow, B, lower down. In A, note one of the vasa brevia arteries passing to the stomach between the layers of the gastro-splenic omentum, and also the foramen of Winslow leading into the lesser sac which lies behind the stomach.

A transverse tracing at a higher level would include the small sac; it will, therefore, be well to study this portion of the peritoneum before describing such a tracing.

Small Sac of the Peritoneum (bursa omentalis).—This, as already pointed

out, is a diverticulum of the great sac which lies behind the stomach and adjacent organs, and which communicates with the great sac by a constricted passage, the foramen of Winslow. If the great sac be compared, as already suggested, to a bag, the anterior layer of which clothes the anterior and lateral walls of the abdomen, and the posterior layer the viscera lying on the posterior wall, the small sac would correspond to a pocket lying behind the upper part of the great sac, and opening into its cavity by a narrow mouth, on the right side, just below the liver. From this opening the pocket passes to the left behind the lesser omentum, as far as the spleen, up behind the Spigelian lobe of the liver, and down behind the stomach, and into the great omentum.

As in the case of the great sac, it will of course be understood that the two walls of the small sac and the boundaries of the foramen of Winslow are normally in contact. We shall first consider this opening, and then trace the layers of the small sac.

Foramen of Winslow (Fig. 709, A).—This, the constricted passage which leads from the great into the small sac of the peritoneum, is found just below and behind the portal fissure of the liver by running the finger along the under surface of the gall-bladder towards its neck, when, with little difficulty, it passes behind the right margin of the lesser omentum and into the foramen. It is *bounded in front* by the free right border of the lesser omentum, passing up from the first part of the duodenum to the portal fissure, and containing between its two layers the portal vein, hepatic artery, and bile duct. *Behind*, lies the inferior vena cava, covered, of course, by peritoneum. *Above*, is placed the caudate lobe of the liver. And *below*, lie the first part of the duodenum, and the hepatic artery, the latter running forwards and to the right beneath the foramen, before turning up into the lesser omentum. It should be remembered that, normally, the various boundaries of the foramen lie in contact, and that its cavity can only be said to exist as such when its walls are drawn apart.

If we follow the small sac, in through the foramen, it will be found that it expands immediately beyond this narrow opening (Fig. 707), its upper portion lying behind the lesser omentum, and running up behind the Spigelian lobe of the liver as far as its upper end; and its lower portion passing down behind the stomach and on into the great omentum, where it lies in front of the transverse colon, and extends practically to the lower end of the omentum—although this latter point cannot often be demonstrated in the adult.

As the small sac is composed, like the great, of two distinct layers, an anterior and a posterior, it will be necessary to follow each of these separately. Above, the **anterior layer of the small sac** clothes the Spigelian lobe; it then passes down (from the posterior margin of the portal fissure, and the fissure of the ductus venosus) to the lesser curvature of the stomach as the posterior layer of the lesser omentum. Continued on from this, it clothes the inferior (or visceral) surface of the stomach as far as the great curvature, with the exception of the small "uncovered area" below and to the left of the cardia (Fig. 674, B), but it does not actually come in contact with the œsophagus itself, the back and right side of which are uncovered. On the left, it is reflected from the back of the stomach to the spleen as the deeper layer of the gastro-splenic omentum.

From the great curvature of the stomach it is continued down, forming the posterior layer (of the anterior fold) of the great omentum; and at the lower part of the omentum it meets and becomes continuous with the posterior layer of the small sac.

The **posterior layer of the small sac,** in passing through the foramen of Winslow, clothes the front of the vena cava (Fig. 709, A); beyond this, it covers the cœliac axis, and passes up to line the slight depression on the posterior abdominal wall (diaphragm), against which the Spigelian lobe rests. Then, passing over to the left, it covers the upper surface of the pancreas, the top of the left kidney and suprarenal capsule, and the inner part of the gastric surface of the spleen (Fig. 710). From the anterior border of the pancreas it is prolonged forwards and downwards—as the anterior or upper layer of the transverse mesocolon—to the transverse colon (Fig. 707). It next clothes the upper aspect of this gut, and is then continued down as the anterior layer of the posterior fold of the great omentum, almost to its lower border, where it becomes continuous with the anterior layer of the small sac, already described.

The transverse tracing at the level of the foramen of Winslow is shown in Fig. 708, A, and can be easily followed without any further description than is there given.

The following additional details may be mentioned :—The small sac is divided by a constriction into two parts—an upper, lying behind the lesser omentum and Spigelian lobe, and a lower, placed behind the stomach and within the great omentum. The constriction is due to the passage of the coronary and hepatic arteries forward around the sac; the former winds round its left side, the latter round its right; and each raises up a fold of peritoneum, which projects strongly into the sac, and partially divides it into two. This can be shown by cutting the lesser omentum along the lesser curvature of the stomach and looking into the cavity.

Where the small sac runs up behind the Spigelian lobe, it forms, as pointed out at page 1065,

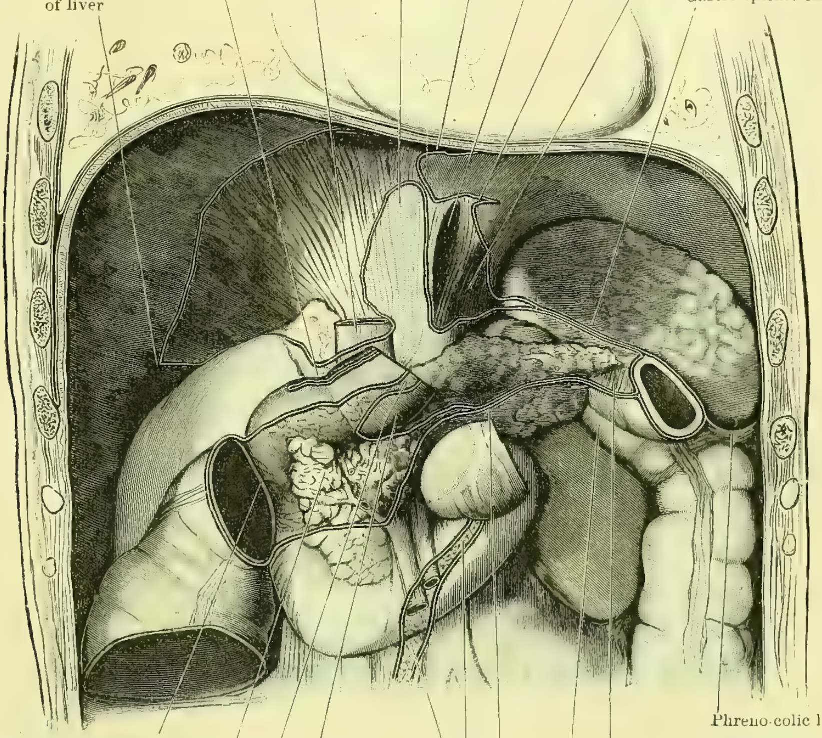


Fig. 710.—The Peritoneal Relations of the Duodenum, Pancreas, Spleen, Kidneys, etc.

the left boundary of the uncovered area of the right lobe, and, consequently, a third or left layer of the coronary ligament.

A special diverticulum of the small sac runs out to the right, behind the beginning of the duodenum, to clothe the back of that tube for about an inch (Fig. 710).

The splenic artery reaches the spleen by passing to the left, behind the posterior layer of the small sac, which also extends to that organ (Fig. 709, A).

The **lesser omentum** is described at page 1066; it need only be pointed out now that it is composed of two layers, the anterior derived from the great sac, and the posterior from the small sac, both of which are extremely thin—sometimes even cribriform.

The **great omentum** is a large apron-like fold of peritoneum, usually more or less loaded with fat, which is suspended from the great curvature of the stomach,

and hangs down in front of the intestines to a variable extent. When the abdomen is carefully opened without disturbing the viscera, it is rare to find the great omentum evenly spread over the front of the intestines. More commonly it is folded in between some of the coils of intestine, or tucked into the left hypochondrium; or perhaps it is carried upwards in front of the stomach by a distended transverse colon. It extends between the great curvature of the stomach above and the transverse colon below, not taking the shortest course from one of these to the other, but hanging down as a loose fold between the two. The lower part of the small sac is continued down within it (Fig. 707).

The great omentum may be said to consist of two folds, each formed of two layers, one derived from each sac of the peritoneum. The **anterior** or **descending fold** begins at the great curvature of the stomach, where it is formed by the meeting of the two layers from the superior and inferior surfaces of that organ respectively; from this it descends to the lower border of the omentum, where, turning back upon itself (Fig. 707), it passes up as the **posterior** or **ascending fold**. This runs upwards until it meets the transverse colon; here its two layers separate to enclose and cover that colon—and the omentum properly so called ceases. Its two layers, however, unite at the upper surface of the colon (Fig. 707) to form the **transverse mesocolon,** which is continued upwards and backwards to the anterior border of the pancreas. Here the layers of the transverse mesocolon again separate—the upper, derived from the small sac, running backwards and upwards over the upper surface of the pancreas to the posterior abdominal wall; the lower, derived from the great sac, passing downwards along the back of the abdomen, as already explained.

The great omentum is continued to the right for a short distance (25 mm.) along the lower border of the duodenum. At the left end it shortens very much, and is directly continued into the gastro-splenic omentum; the spleen, as it were, being introduced between the two layers instead of the colon.

Functions of the Great Omentum.—Numerous uses have been assigned to the great omentum; the chief seem to be: (1) To act as a movable packing material, capable of filling all temporarily-produced spaces in the abdomen. (2) It probably, to some extent, prevents the passage of the small intestine up into the stomach chamber, and helps to keep them from getting entangled there. (3) It is a storehouse of fat. (4) It is said to be "the great protector against peritoneal infectious invasions." Being freely movable, it can pass to almost any part of the abdomen, and there "build up barriers of exudations to check infection" (Byron Robinson).

Mr. Lockwood has made the interesting observation (in connexion with the contents of herniæ) that, in bodies under forty-five years of age, the omentum can rarely be drawn down below the level of the pubic spine; in older bodies the reverse is the rule.

The **gastro-splenic omentum** is a short fold composed of two layers, the anterior or more superficial being derived from the great sac, the posterior or deeper from the small sac (Fig. 709, A). It is attached by one margin to the wide end of the stomach (just below the line of the great curvature), and by the other to the gastric surface of the spleen just in front of the hilus. Between its two layers the vasa brevia of the splenic artery pass from the spleen to the stomach. Below and in front, its layers are continued into the corresponding layers of the great omentum; above and behind, they separate at the "uncovered area" of the stomach (Fig. 710).

Minor Folds of Peritoneum.—The **phreno-colic ligament,** passing from the splenic flexure of the colon to the diaphragm opposite the 10th or 11th ribs, has been described in connexion with the splenic flexure. The **mesentery of the appendix,** and the folds and fossæ around the ileo-cæcal region, are included in the account of the cæcum, as are those around the duodenum in the description of that viscus. The **lieno-renal** and **hepato-renal** ligaments have been referred to incidentally above.

Development of the Intestinal Canal and Peritoneum.

As already explained on p. 31, when the embryo begins to take definite shape, and to be marked off from the general surface of the blastodermic vesicle by an infolding of its margins—resulting in the formation of the cephalic or head fold, the caudal or tail fold, and the lateral folds—a portion of the cavity of the vesicle is cut off by these folds, and more or less completely enclosed within the body of the embryo, to form the **primitive alimentary canal.** This is simply an imperfect tubular cavity, situated beneath the

notochord, and bounded towards one end by the head fold, at the other by the tail fold, and at the sides by the lateral folds. The anterior portion of this cavity, situated within the head fold, is known as the **foregut**, and from it are developed the back part of the mouth, the tongue, pharynx, œsophagus, stomach, and the greater portion of the duodenum, together with the organs formed as outgrowths from these. Similarly, the posterior tubular portion, contained within the tail fold, constitutes the **hindgut**, and from it are formed the rectum, except its anal end, and a portion of the colon. The middle division, known as the **midgut**, gives rise to the rest of the digestive tube, and is at first widely open below, where it is continuous with the cavity of the yolk sac. Soon, however, it is gradually closed in by the approximation of the four folds which meet around the margins of the umbilical orifice, and the communication between the alimentary canal and the yolk sac is thus reduced to a narrow passage—the **vitelline** or **vitello-intestinal duct.** This duct joins that portion of the primitive tube which subsequently forms the lower part of the ileum, and a remnant of it is sometimes found in the adult, when it is known as **Meckel's diverticulum** (see p. 1022).

At this stage the primitive canal has the form of a nearly straight tube, blind at both extremities, and communicating only with the cavity of the yolk sac. It is lined throughout by the entoderm, the cells of which form the epithelial lining of the adult canal; outside this it is invested by the splanchnopleure, or splanchnic layer of the mesoderm, and is separated from the somatopleure or body wall by the **cœlum** or **body cavity,** which later on gives rise to the pleural, pericardial, and peritoneal cavities of the body. At the back, the splanchnic mesoderm which surrounds the canal passes dorsalwards, to become continuous with the general mesoderm beneath the notochord, thereby forming a fold which connects the primitive alimentary tube to the dorsal wall of the embryo, and constitutes the **primitive mesentery.** This is at first of considerable thickness. At a later period it becomes reduced to a thin sheet of mesodermic tissue, covered on each side by a layer of flattened endothelial cells, which suspends the primitive alimentary canal within the body cavity of the embryo.

At each end of the embryo, an ingrowth of the ectoderm takes place, which meets and finally becomes continuous with the corresponding extremity of the primitive alimentary tube, giving rise to the mouth and anus respectively. The former of these ingrowths is known as the **stomatodæum**, and from it is formed the epithelial lining of the vestibule of the mouth, of the salivary glands, the gums, and the greater part of the nasal cavity, as well as the anterior lobe of the pituitary body. From the other ingrowth—the **proctodæum** —are formed the anal aperture and probably the anal canal, below the level of the anal valves. An account of the formation of the mouth and the anus will be found on pages 32 and 43 respectively.

At an early date special outgrowths of the lining entoderm take place from the portion of the foregut corresponding to the future duodenum. From these diverticula the liver and pancreas are formed: the former grows forwards from the gut, whilst the latter grows backwards into the dorsal mesentery (see pages 1072 and 1078 respectively).

The primitive alimentary canal is now a tubular cavity, suspended from the dorsal wall of the embryo, within the cœlom, by a simple mesentery (Fig. 711). In front, it communicates with the exterior through the stomatodæum or primitive mouth, and in the region of the future duodenum the liver appears as a bifid outgrowth, followed soon by outgrowths for the formation of the pancreas. Finally, at a date which has not been precisely determined, the anal membrane disappears, and its posterior end communicates with the exterior through the proctodæum.

Stomach.—As early as the fourth week the foregut exhibits a fusiform enlargement in the region of the developing heart, which is the first evidence of the differentiation of the stomach: this enlargement is at first symmetrical, and mesially placed. Soon, however, as the diaphragm is being formed, the stomach descends into the abdomen, and its dorsal wall—the future great curvature—begins to grow more rapidly than the ventral wall. As a result the whole organ becomes somewhat curved, and its lower end is carried forwards from the posterior abdominal wall, giving rise to the curvature of the duodenum. The excessive growth of its posterior wall causes the stomach to turn over on to its right side, which now becomes posterior or dorsal. In this rotation its upper or cardiac portion moves to the left of the middle line, and the whole organ assumes an oblique direction across the abdomen. Already, at the fifth or sixth week, the adult form of the stomach is pretty clearly indicated.

This rotation of the stomach around its long axis, which is accompanied by a rotation of the lower end of the œsophagus, explains the unsymmetrical position of the two pneumogastric nerves In the adult the left nerve is found on the front of the stomach,

which was originally the left side of the organ; similarly, the right nerve lies on the back, which was originally the right side.

Intestines.—At first there is no separation into large and small intestines; the primitive canal simply forms a slender tube, with a convexity towards the umbilical orifice, through which the vitelline duct passes to the yolk sac. Later, the tube increases in length, and in embryos of 11 or 12 mm. an outgrowth of the canal appears, which represents the future cæcum, and indicates the separation into large and small intestines. Growing longer, the intestine forms a large loop with the vitelline duct springing from its apex (Fig. 711) and the superior mesenteric artery, running down between the layers of its mesentery. At the same time the two extremities of the coil approach one another, and form a narrow neck to the loop, as shown in Fig. 711. There now takes place a change which entirely modifies the position of the parts—this is a rotation of the whole loop, with its mesentery, around the superior mesenteric artery as an axis (Fig. 711). The result of this rotation is that the original right side of the loop of gut and mesentery becomes the left side; and the beginning of the large intestine is carried across the duodenum (Fig. 712), thus explaining the passage of the duodenum behind the transverse colon in the adult. At the same time the cæcum comes to lie near the middle of the abdomen below the liver, a position in which it will be found during the third month. Subsequently, it passes further to the right; and finally, descending, comes to occupy its adult position.

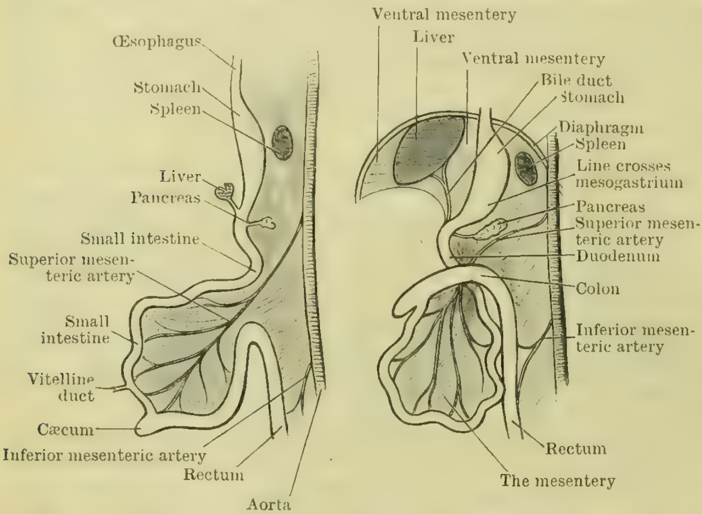


FIG. 711.—TWO DIAGRAMS TO ILLUSTRATE THE DEVELOPMENT OF THE INTESTINAL CANAL.

The figure to the right shows the rotation of the intestinal loop round the superior mesenteric artery. In both figures the parts are supposed to be viewed from the left side.

The small intestine continues to grow in length, and, as a result, is thrown into coils, which become more and more complex as the length increases, until the adult condition is attained. The terminal portion of the large bowel retains its position on the left side, and passes down to the anus. The development of the cæcum and appendix is described at page 1027.

Peritoneum.—At first the primitive alimentary canal is suspended from the dorsal wall of the embryo, along the middle line, by a **simple dorsal mesentery**, which extends along the whole length of the tube, and is common to all its divisions—a condition found in the adult stage of many reptiles. There is also present, in the upper part of the cavity, after the stomach and liver descend into the abdomen, a **ventral mesentery** (Fig. 711), which connects the stomach and duodenum to the back of the liver, and, passing on, connects the front of the liver to the anterior abdominal wall. The portion of this ventral mesentery, between the stomach and liver, becomes the lesser omentum; its anterior portion, between the liver and the abdominal wall, forms the falciform ligament (Fig. 711); and, in its lower margin, the umbilical vein runs from the umbilicus to the liver.

The portion of the dorsal mesentery lying behind the stomach is known as the **mesogastrium.** At first it is relatively short; but with the growth of the posterior wall of the stomach, and the turning of that organ over on its right side, the mesogastrium becomes elongated, and is folded on itself, forming more or less of a pouch, directed downwards and to the left. The wall of this pouch becomes in part the great omentum, and within it is developed the small sac of the peritoneum. In the rotation of the stomach and the accompanying passage of the lesser omentum from an antero-posterior to a more or less transverse direction, a portion of the cavity of the abdomen is, as it were, caught in

behind the stomach and lesser omentum. This portion of the cavity becomes the upper part (vestibule) of the small sac, and at first it communicates with the general cavity by a wide opening to the right of the lesser omentum; but the growth of the liver, encroaching upon the opening, and other causes, reduce it to a relatively small size, and it forms the **foramen of Winslow** in the adult.

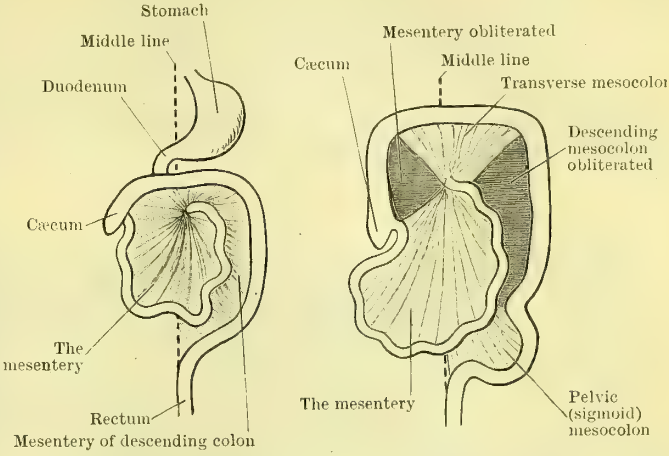


FIG. 712.—TWO DIAGRAMS TO ILLUSTRATE THE DEVELOPMENT OF THE MESENTERIES.

In the first figure the rotation of the intestinal loop and the continuous primitive mesentery is shown. In the second figure (to the right), which shows a more advanced stage, the portions of the primitive mesentery (going to the ascending and descending colons) which disappear, through their adhesion to the posterior abdominal wall, are shaded dark; the portions which persist are lightly shaded.

The **great omentum** is, as pointed out above, a bag-like growth of the lower part of the mesogastrium, which passes downwards and to the left in front of the transverse colon. As shown in Fig. 713, A and B, it is at first entirely unconnected with the transverse colon and mesocolon; but about the third or fourth month it becomes united to both, and the adult condition is established (Fig. 713, C).

It would appear that the growth of the lower part of the small sac, and of the great omentum, is primarily due to a proliferation of the cells over a limited area of the mesogastrium, and a resulting folding of this layer downwards and to the left.

In the upper part of the mesogastrium the **spleen** is developed, and the portion of this fold which intervenes between the stomach and spleen forms the gastro-splenic omentum, whilst the part behind the spleen becomes the lieno-renal ligament.

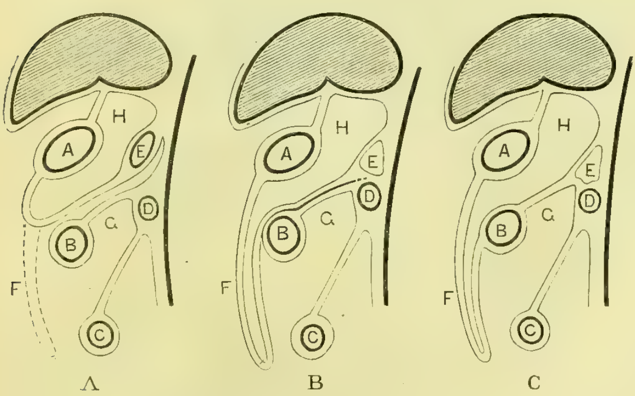


FIG. 713.—DIAGRAMS TO ILLUSTRATE THE DEVELOPMENT OF THE GREAT OMENTUM (after Hertwig).

A, shows the beginning of the great omentum and its independence of the transverse mesocolon; in B, the two come in contact; and in C, they have fused along the line of contact. (According to Lockwood, the two layers of the fold shown in A, running in between the great omentum and transverse mesocolon, instead of fusing, as shown in B, are drawn out—unfolded—producing the condition shown in C). A, stomach; B, transverse colon; C, small intestine; D, duodenum; E, pancreas; F, great omentum; G, placed in great sac; H, in small sac of peritoneum.

Of the primitive mesentery, the portion connected with the stomach — the mesogastrium — becomes modified in the manner just described. The next division—the mesoduodenum — disappears completely, owing to the turning over of the duodenal loop on to its right side, and its subsequent adhesion to the posterior abdominal wall, accompanied by the absorption of its mesentery. The mesenteries of the small and large intestine are continuous at first (Fig. 711). When the rotation of the intestinal loop takes place around the superior mesenteric artery (see above), the beginning of the large intestine, with its mesentery, is carried to the right across the duodenum, and a fan-shaped portion of the general mesentery, lying within the concavity of the loop, is partially cut off; this, later on, forms the mesentery proper in the adult. At first it is continuous by its right border with the mesentery of the ascending colon, a part of the primitive mesentery (which is similarly continued into the mesentery of the transverse, descending, iliac, and pelvic colons). Subsequently, as

shown by the darkly-shaded parts in Fig. 712, the back of the mesenteries of the ascending, descending, and iliac portions of the colon, adheres to the posterior abdominal wall, and these mesenteries become lost; whilst the mesenteries of the transverse and pelvic portions of the colon remain free, and persist in the adult.

At the same time, the mesentery proper (which was at first attached only at its narrow neck, between the duodenum and transverse colon, and below this was continuous on the right with the ascending mesocolon), now acquires a new attachment to the posterior abdominal wall through the absorption of the ascending mesocolon (Fig. 712), and the adult condition is attained.

THE LIVER.

The **liver** (hepar) is a large glandular mass of irregular shape, which lies under cover of the ribs in the upper and right portion of the abdominal cavity, immediately beneath the diaphragm (Fig. 714). It is the largest of all the digestive glands, and plays an important part in the metabolism of both carbohydrate and nitrogenous materials: in addition, it secretes the bile — a fluid which although chiefly excretory, assists to some extent in pancreatic digestion. From the liver the bile is conveyed to the duodenum by the *bile duct*, in connexion with which is found a pear-shaped diverticulum, for the temporary storage of the bile, known as the *gall-bladder* (Fig. 716).

Form.—The liver is so irregular, and varies so considerably in size and shape in different bodies, and even in the same body under different conditions, that it is difficult to convey a true idea of its form. This, perhaps, may be most readily realised from a consideration of the portion of the abdomen in which the liver lies, and to the shape of which its form is chiefly due.

The upper portion of the abdominal cavity is dome-shaped, its anterior, posterior, and lateral walls, as well as its roof, being formed chiefly by the vaulted under surface of the diaphragm, which slopes down on the inner aspect of the ribs as far as the lower border of the thoracic framework. In the right and middle portions of the dome-shaped space thus formed the liver lies, like a cast in its mould, and from it chiefly its form is derived. And, if an imaginary plane be passed backwards and upwards, from an oblique line extending across the anterior abdominal wall, from a point immediately below the right margin of the ribs to a point one inch below the left nipple, it will cut off a segment of the abdominal cavity which corresponds tolerably accurately to the liver, in both size and form.

Accordingly, the liver may be described as having two chief surfaces: a *parietal surface*, convex in general outline, which fits into the arch of the diaphragm; and a *visceral surface*, irregular in form, which looks downwards, backwards, and to the left, and rests upon the abdominal viscera. These two surfaces are separated from one another by the *inferior margin* of the liver.

Symington has described the liver, when hardened *in situ*, as a right-angled triangular prism with its right angles rounded off, and as having five surfaces—anterior, posterior, superior, right, and inferior. The first four of these would be included in the parietal surface described above, and the inferior corresponds to the visceral surface. Symington's description has received a very wide acceptance.

Previously His had described three surfaces: an inferior, corresponding to the visceral, and a superior and posterior, which together correspond to the parietal surface.

Before His's description, which changed all previous views on the form of the liver, became current, it was described as having two surfaces, an upper and a lower, and two borders, an anterior thin and a posterior thick; and this is the shape of the ordinary soft dissecting-room liver, which flattens out into a cake-like form when removed from the body.

In the body, on the other hand, instead of being flattened out in this way, it is folded, as it were, around its portal and longitudinal fissures into a much more compact mass; and if hardened *in situ* before its removal, it presents an appearance very different from that of the soft liver just referred to. From a study of such hardened specimens it will be seen that the mass of the right lobe lies chiefly in an antero-posterior direction, its posterior thick portion fitting into a wide groove at the side of the vertebral column, and its long axis running from behind forwards and a little inwards. The left lobe, leading off from the anterior part of the right lobe, is folded across the front of the vertebral column and great vessels, its long axis running transversely, but it does not usually pass back at the side of the vertebral column, like the right lobe, into the vertebral groove; so that there is no real notch, as usually described, at the back of the liver for the

vertebral column, but merely an angle formed by the meeting of the two lobes coming from different directions.

Position.—The main mass of the liver lies in the right hypochondrium; from this it extends across the upper part of the epigastrium, and usually reaches as far as the left Poupart plane. Not uncommonly, however, it passes into the left hypochondrium, where it may extend even as far as the left lateral wall of the abdomen. Usually, too, its lower margin passes down on the right side for a little distance (½ inch, 12·5 mm.) below the subcostal plane, and comes to lie in the

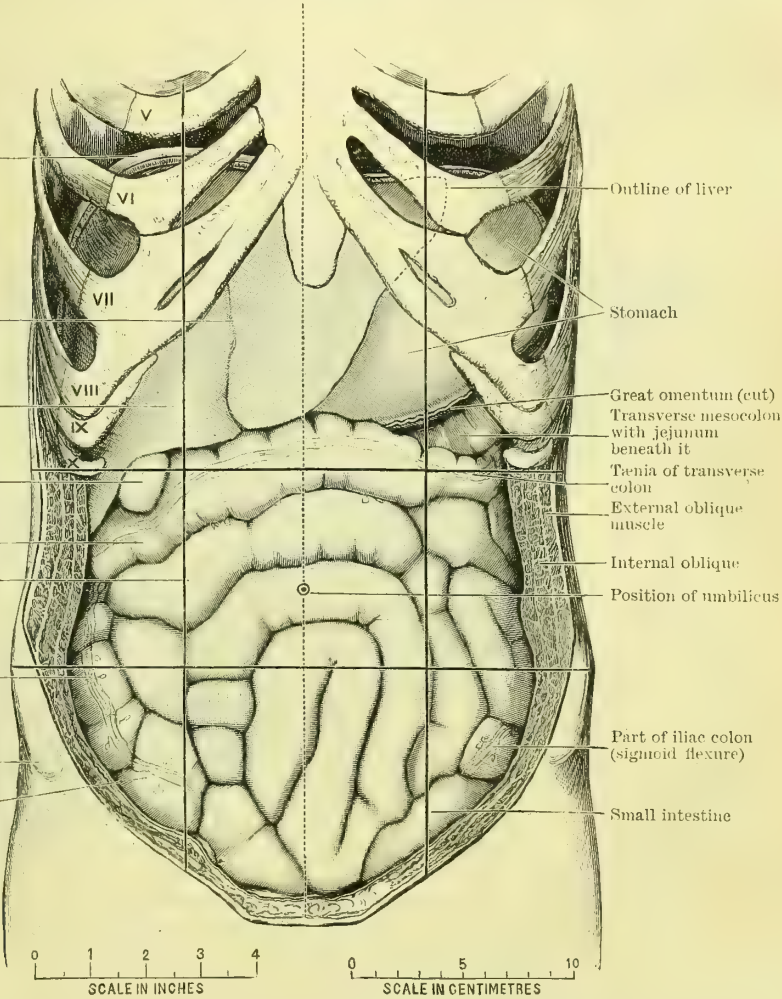


FIG. 714.—THE ABDOMINAL VISCERA IN SITU, as seen when the abdomen is laid open and the great omentum removed (drawn to scale from a photograph of a male body aged 56, hardened by formalin injections).

The ribs on the right side are indicated by Roman numerals; it will be observed that the eighth costal cartilage articulated with the sternum on both sides. The subcostal, intertubercular, and right and left Poupart lines are drawn in black, and the mesial plane is indicated by a dotted line. The intercostal muscles and part of the diaphragm have been removed, to show the liver and stomach extending up beneath the ribs. The stomach was moderately distended, and the intestines were particularly regular in their arrangement.

right lumbar region. Under ordinary conditions, the anterior end of the longitudinal fissure, which separates the right from the left lobe, lies one or two inches to the right of the mesial plane.

The limits even of the normal liver are very variable, but, taking the average condition in the male, they may be marked out on the surface of the body by the following method:—Three points are determined—(*a*) half-an-inch (12·5 mm.) below the right nipple; (*b*) half-an-inch (12·5 mm.) below the right margin of the thorax (or below the tip of the tenth rib); and (*c*) one inch (25 mm.) below the

left nipple. If these points be joined by three lines, slightly concave towards the liver, they will give the outline of the organ with sufficient accuracy for all ordinary purposes. (For variations in position see p. 1067.)

Or in more detail:—if the two "nipple points" (*a*) and (*c*) be joined by a line, slightly convex upwards on each side, but a little depressed at the centre corresponding to the position of the heart, and crossing the lower end of the sternum about the level of the sixth cartilage, it will mark the upper limit. A line, convex outwards, from the right nipple point (*a*) to the subcostal point (*b*) will indicate the right limit, while the lower limit is marked by a line, convex downwards, drawn from the subcostal point (*b*) to the left nipple point (*c*), and passing through a point half-way between the umbilicus and the lower end of the gladiolus, in the middle line.

The line indicating the *upper limit of the liver* is elevated on each side, corresponding to the cupolæ of the diaphragm, and depressed in the centre beneath the heart. On the right side where highest, namely, about one inch (25 mm.), internal to the mammary line, it reaches during expiration to the upper border of the fifth rib; on the left side it is one-half to three-quarters of an inch (12 to 18 mm.) lower; and it crosses behind the sternum at the level of the sixth sterno-costal junction—or sometimes lower. It must be remembered, however, that, whilst the liver reaches up to the levels just given, it does so only at the highest part of its convex parietal surface, and is separated from the ribs all round by the thin lower margin of the lung (which extends down between the chest wall and diaphragm to the sixth rib in front, to the eighth in the mid-lateral line, and to the level of the tip of the spine of the tenth dorsal vertebra behind), so that, in percussing over the liver, its dulness is obscured by the resonance of the lungs above these points.

Weight and Size.—The liver usually weighs from three to three and a quarter pounds, or about $\frac{1}{40}$th of the body weight.

The average size of the liver may be briefly expressed as follows:—It measures in the transverse direction about seven inches (17·5 cm.); in the vertical, six to seven inches (15 to 17·5 cm.); and in the antero-posterior, on the right side where greatest, about six inches (15 cm.) Its greatest width, measured obliquely from side to side along the inferior or visceral surface, is ten inches (25 cm.)

Its weight ordinarily varies between fifty and fifty-five ounces in the male, and between forty-three and forty-eight in the female, with an average for the two sexes of about forty-nine ounces, or a little over three pounds. It corresponds to about $\frac{1}{40}$th of the body weight in the adult; whilst at birth it is relatively twice as large (viz. $\frac{1}{18}$th or $\frac{1}{20}$th of the body weight), and in the early fœtus very much larger.

The proportion of the right to the left lobe is very variable, but is usually about as 4 to 1; at birth it is about as 2 or 3 to 1.

Relations and Surfaces.—The liver, as already pointed out, possesses two chief surfaces, the parietal lying in contact with the abdominal parietes, and the visceral resting on the abdominal viscera.

Parietal Surface.—In conformity with the shape of the upper portion of the abdominal cavity which it occupies, the parietal surface (Fig. 715) is convex in general outline, and, taken as a whole, lies against the diaphragm, except below and in front, where it projects from beneath the ribs (Fig. 714), and comes in contact with the anterior abdominal wall for about two or three inches (5·0 to 7·5 cm.) below the xiphi-sternal articulation. It is completely covered by peritoneum, except behind at the "uncovered area," where it comes into direct relation with the diaphragm; and it is divided into right and left lobe-portions by the attachment of the falciform ligament—a fold of peritoneum which connects it to the diaphragm and anterior abdominal wall.

As the space which the liver occupies is bounded by the anterior, the right, and the posterior walls of the abdomen, as well as by the roof, we can distinguish on its parietal surface, which lies against, and takes its shape from, these walls, four corresponding "areas," namely (*a*) the superior, (*b*) the anterior, (*c*) the right, and (*d*) the posterior areas of the parietal surface. Of these the posterior area is the most important, and must be described in greater detail than the others.

Posterior Area, or back, of the Parietal Surface.—This portion of the parietal surface (which corresponds to the posterior surface of His) is directed backwards, and lies in contact with the diaphragm, here passing down on the posterior abdominal wall. It is very irregular in shape, and presents from right to left the following parts:—(1) The "uncovered area" of the right lobe; (2) the suprarenal impression; (3) the fossa of the vena cava; (4) the Spigelian lobe, separated by the fissure of the ductus venosus from (5) the œsophageal groove, which belongs to the left lobe.

"bare area"
(1) The "**uncovered area**" of the right lobe (Fig. 716) is a considerable portion of the back of the right lobe—varying from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches (3·7 to 6·2 cm.) in width, and from 3 to 4 inches (7·5 to 10 cm.) in transverse measurement—which corresponds to the interval between the two layers of the coronary ligament, and is devoid of peritoneum. Over this uncovered portion, which looks more inwards than backwards, the liver and diaphragm are in direct contact, and are united by areolar tissue; here too is established a communication by small veins between the portal circulation of the liver and the systemic circulation of the diaphragm.

(2) **Suprarenal Impression.**—On the "uncovered area," immediately to the right of (and behind) the vena cava, is a triangular impression (impressio suprarenalis, Fig. 716), produced by the suprarenal body, which, projecting upwards from the top of the right kidney, becomes wedged in between the diaphragm and liver.

(3) **Fossa of the Vena Cava** (fossa venæ cavæ).—At the left extremity of the "uncovered area" the inferior vena cava lies vertically, embedded in a fossa

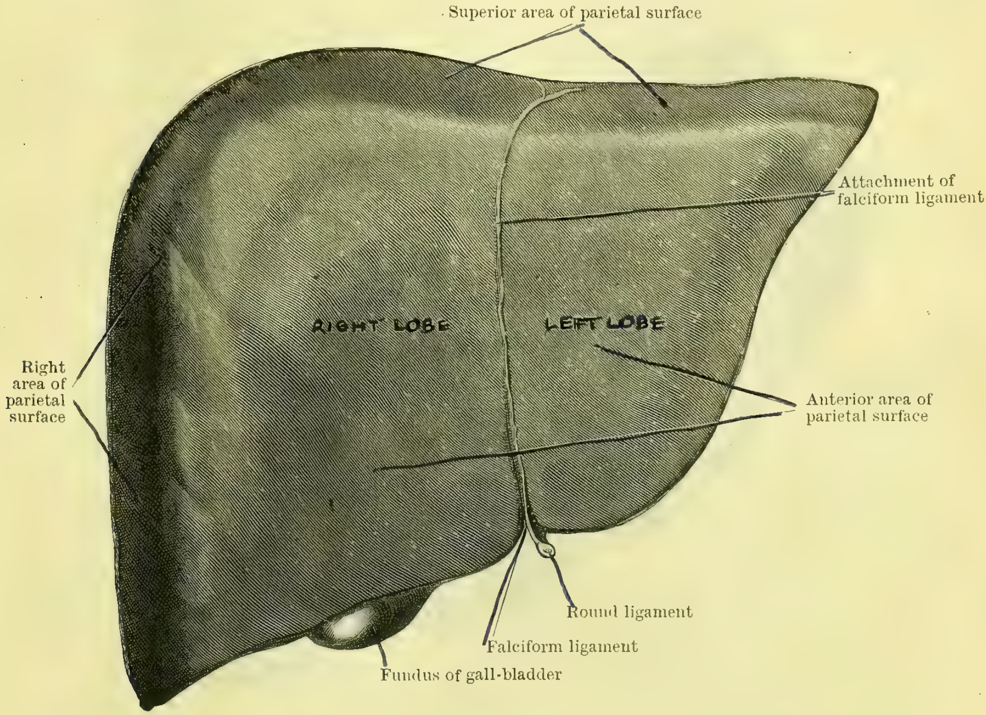


FIG. 715.—THE LIVER FROM THE FRONT, showing the superior, right, and anterior areas of the parietal surface.

of the liver substance, between the Spigelian lobe on the left and the adjacent part of the uncovered area on the right, both of which project over the sides of the cava, almost hiding it from view (Fig. 716); sometimes they actually meet and form a **pons hepatis** across the back of the vein.

(4) **Spigelian Lobe.**—To the left of the fossa of the cava lies the Spigelian lobe (lobus caudatus), a prominent oblong mass (Fig. 716), which is placed vertically on the back of the liver, between the fissure of the ductus venosus on the left and the fossa of the vena cava on the right—the former marking it off from the left lobe, the latter from the "uncovered area" of the right lobe. The top of the small sac of peritoneum separates the back of the Spigelian lobe from the diaphragm, which latter, in turn, separates it from the aorta just before that vessel enters the abdomen.

The upper end of the Spigelian lobe is separated from the superior area of the parietal surface by the meeting of the vena cava and the fissure of the ductus venosus in front of it. Its lower end is free and prominent, and reaches to the visceral surface, where it usually presents a notch or fissure (in which the hepatic artery lies, particularly in the fœtus), which marks off a larger and more prominent left part (the tuberculum papillare) projecting downwards behind the

portal fissure, and a smaller right part passing out into the processus caudatus, or caudate lobe, which connects it (Fig. 716) with the under or visceral surface of the right lobe.

The posterior surface of the Spigelian lobe is free; it is placed vertically, and looks backwards and slightly inwards. The lobe has also another surface, which is hidden when in the body and in the hardened liver by the folding of the left lobe across it. By this folding there is formed a deep fissure (fissure of the ductus venosus), at the bottom of which will be found the remains of the ductus venosus.

(5) The **Œsophageal Groove** is situated on the back of the left lobe, to the left of the upper end of the Spigelian lobe, but separated from it by the fissure of the ductus venosus (fossa ductus venosi), which on this aspect indicates the division between the right and left lobes. The groove leads down into the gastric impres-

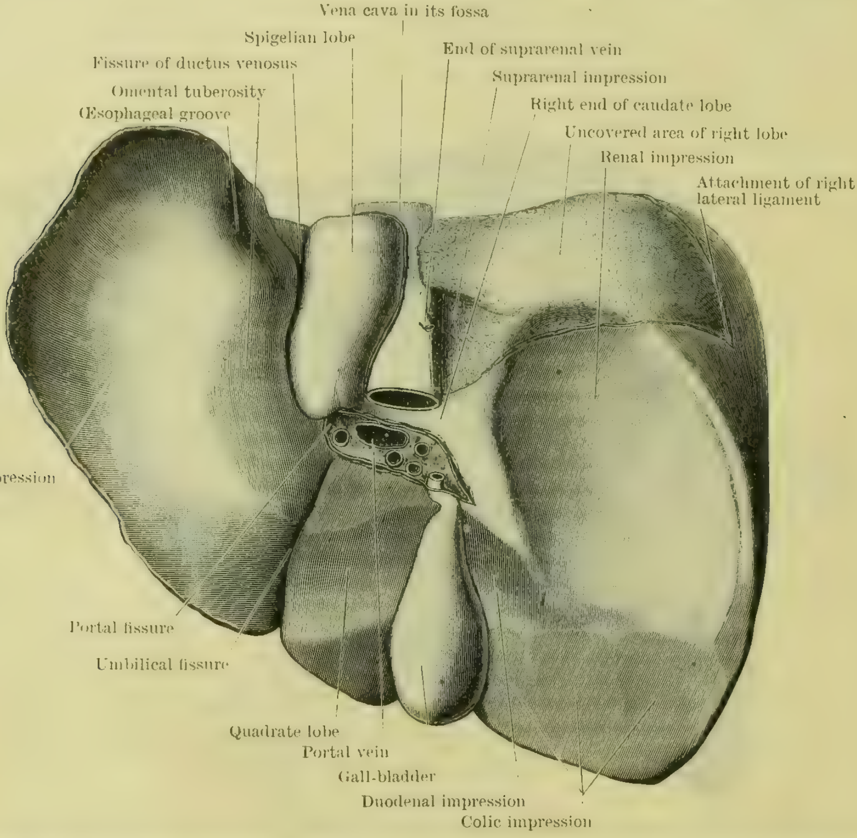


FIG. 716.—THE LIVER FROM BELOW AND BEHIND, showing the whole of the visceral surface and the posterior area of the parietal surface. The portal fissure has been slightly opened up to show the vessels passing through it; the other fissures are represented in their natural condition—closed. In this liver, which was hardened *in situ*, the impressions of the sacculations of the colon were distinctly visible at the colic impression. The round ligament and the remains of the ductus venosus are hidden in the depths of their fissures.

sion on the visceral surface of the left lobe (Fig. 716), and, when in the body, lies in contact with the prominent right or anterior margin of the œsophageal orifice of the diaphragm (see p. 990 and Fig. 724), sometimes also with the œsophagus itself.

The **superior area** of the **parietal surface** lies in contact with the roof of the abdomen; it is convex on each side, and depressed near the middle line. The two convexities, of which the right is the more prominent, fit into the two cupolæ of the diaphragm; whilst the central depression (depressio cardiaca) corresponds to the position of the heart. This area (with the exception of a small triangle at its posterior part, between the separating layers of the falciform ligament) is completely covered by peritoneum, and on it the division of the liver into right and left lobes is indicated by the attachment of the falciform ligament.

The **anterior area** of the **parietal surface** is triangular in shape, and after death is usually flattened, owing to the falling in of the anterior abdominal wall. In part it lies in contact with the diaphragm, which separates it from the rib-cartilages on each side, but at the subcostal

triangle it comes into direct relation with the anterior wall of the abdomen, for a distance usually of two or three inches below the xiphi-sternal articulation. It has a complete peritoneal covering, and gives attachment as far down as the umbilical notch, at the inferior border, to the falciform ligament, which connects it to the anterior abdominal wall.

The anterior passes gradually into the upper and right areas, but it is distinctly separated from the visceral surface by the sharp inferior border of the organ. The umbilical notch is often continued upwards for some distance on this surface as a slit-like fissure.

The **right area** of the **parietal surface** is convex and extensive, and lies in contact with the diaphragm, which separates it from the inner surface of the lower ribs, and also from the lower margin of the lung and pleura above. Though sharply marked off by the inferior border from the visceral surface, it passes without distinct limits into the other areas of the parietal surface. It is completely covered by peritoneum.

Visceral or Inferior Surface.—This surface of the liver is an irregular, obliquely sloping surface (Fig. 716), which looks downwards, backwards, and to the left, and rests upon the stomach, intestines, and right kidney—all of which leave impressions upon it. The division into right and left lobes is indicated on this surface by the umbilical fissure, which passes from the umbilical notch at the anterior border, back to the portal fissure.

The visceral surface of the *left lobe* is directed downwards and backwards, and rests on the upper surface of the stomach, in front of the cardia; also on the lesser curvature with its attached lesser omentum. The part which rests upon the upper surface of the stomach is rendered concave by the pressure of that organ (Fig. 716), and is known as the **gastric impression** (impressio gastrica); whilst the portion to the right of this, being free from the pressure of the stomach, projects backwards over the lesser curvature against the lesser omentum, and is known as the **omental tuberosity** (tuber omentale).

The visceral surface of the *right lobe* may be divided into two portions by the line of the gall-bladder, which extends forward in its fossa to the lower sharp margin of the liver (Fig. 716).

(**a**) *To the left of the line of the gall-bladder* are found from before backwards:—The quadrate lobe, portal fissure, and caudate lobe. (1) The **quadrate lobe** (lobus quadratus) is placed at the anterior part of the under surface, between the gall-bladder and the umbilical fissure, extending to the inferior margin of the liver in front, and to the portal fissure behind: it rests upon the pylorus or the beginning of the duodenum. (2) The **portal** or **transverse fissure** is a wide cleft through which the portal vein, hepatic artery, and hepatic duct enter the liver, and to the margins of which are attached the two layers of the lesser omentum (Fig. 716). (3) The **caudate lobe** or **process** (processus caudatus) consists of a narrow ridge of liver substance which runs across behind the portal fissure, and connects the lower end of the Spigelian lobe with the rest of the right lobe. It forms the upper boundary of the foramen of Winslow, and is felt when the finger is introduced into that passage. It is often very small, and occasionally can scarcely be distinguished.

(**b**) *The surface to the right of the gall-bladder*, which is more extensive than that on its left, is entirely occupied by three impressions produced by the underlying viscera—namely: (1) The **colic impression** (impressio colica) lies in front and to the right of the gall-bladder. It rests upon the hepatic flexure and the beginning of the transverse colon. (2) Behind this is the **renal impression** (impressio renalis), larger than the preceding, which corresponds in size and form to the upper half or two-thirds of the right kidney, against the anterior or visceral surface of which it lies. It is placed behind the colic impression just as the kidney itself is placed behind the colon. (3) To the inner side of the renal impression, and near the neck of the gall-bladder, is placed the narrow **duodenal impression** (impressio duodenalis) which lies in contact with the duodenum (the second part, down to the point at which it is crossed by the colon).

The **quadrate lobe** is of an oblong shape, the antero-posterior diameter being the greatest. Its surface is generally concave, and is related to the pylorus and the adjacent parts of the stomach and duodenum, when the former is distended. When the stomach is empty, however, the pylorus usually lies beneath the right portion of the left lobe, and the first part of the duodenum lies beneath the quadrate lobe, the transverse colon also coming in contact with it anteriorly (Fig. 716).

The upper end of the renal impression is frequently uncovered by peritoneum (Fig. 716), that

is to say, the "uncovered area" of the right lobe extends down over the impression for a little way. This impression is very deep, and accommodates nearly the whole thickness of the kidney. In many hardened specimens it would appear to belong more to the posterior part of the parietal than to the inferior or visceral surface.

The **inferior margin of the liver**, as already pointed out, separates the parietal from the visceral surface. *Behind*, it is indistinctly marked and corresponds to the lower edge of the posterior area, or back, of the parietal surface: it is in contact with the right kidney, and runs along the course of the eleventh rib. *At the right side* it is stout but distinct, and usually corresponds to, or projects a little way below, the lower border of the thoracic framework. *In front* (margo anterior) it is thin and sharp, and crosses the anterior abdominal wall obliquely, generally corresponding to a line drawn from a point half an inch (12 mm.) below the margin of the ribs (tip of tenth costal cartilage) on the right side to a point an inch below the nipple on the left, and extending down in the middle line to a point half-way between the gladiolus and the umbilicus. This portion of the lower border usually, but not invariably, presents one or two notches. The **umbilical notch** (incisura umbilicalis), by much the more constant of the two (Fig. 715), is situated at the anterior end of the umbilical fissure, and corresponds to the lower part of the attachment of the falciform ligament. It is usually placed from one to two inches (2·5 to 5·0 cm.) to the right of the middle line. The second notch, less frequently present, corresponds to the fundus of the gall-bladder, and may be called the **notch of the gall-bladder** (incisura vesicæ felleæ).

At its left extremity the inferior margin passes backwards around the edge of the left lobe, and ends at the œsophageal groove on its back.

Fissures of the Liver.—Five fissures or fossæ are usually described in connexion with the liver; these are: (1) the umbilical fissure, (2) the fissure of the ductus venosus; (3) the portal fissure; (4) the fissure, or fossa, of the gall-bladder; and (5) the fissure, or fossa, of the vena cava.

Taken together, the five fissures are arranged somewhat in the form of the letter A (Fig. 716); the two lower divisions of the diverging limbs being formed by the umbilical fissure and the fissure of the gall-bladder respectively, and the cross-piece by the portal fissure—all of which are placed on the inferior or visceral surface. The two upper divisions of the limbs are represented by the fissure of the ductus venosus and that of the vena cava, which meet above and are both placed on the back or posterior area of the parietal surface. The latter of these two—namely, the fissure of the cava, represented by the right upper division of the A—does not join the cross-piece (the portal fissure), but is separated from it below by a narrow ridge of liver substance—the caudate lobe or process (Fig. 716).

(1) The **umbilical fissure** (fossa venæ umbilicalis) is a deep crevice-like fissure, situated on the visceral surface between the adjacent portions of the quadrate and left lobes. At its bottom is seen a stout fibrous band, the round ligament—the remains of the umbilical vein of the fœtus. The fissure leads from the umbilical notch at the inferior border of the liver to the left extremity of the portal fissure (Fig. 716), and is very often crossed by a **pons hepatis**—a band of liver substance—which may even extend along the whole length of the fissure, hiding the round ligament completely from view.

(2) The **fissure of the ductus venosus** (fossa ductus venosi) lies on the back of the parietal surface of the liver and separates the Spigelian from the left lobe (Fig. 716). It joins the portal fissure below, opposite the umbilical fissure; and above, it meets the fissure of the vena cava. On separating its sides there is found at its bottom a fibrous band, usually much thinner than the round ligament: this is the remains of the ductus venosus of the fœtus.

The umbilical fissure and the fissure of the ductus venosus taken together constitute the **longitudinal fissure of the liver** (fossa longitudinalis sinistra), which separates the right from the left lobe on both the inferior and posterior aspects. It will be observed that all other fissures and all other lobes (except the left) lie to the right of the longitudinal fissure, and therefore are situated on the right lobe.

(3) The **portal** or **transverse fissure** (porta hepatis) when examined in the unhardened liver appears as a wide depression, bounded by prominent lips, which runs

to the right, from the middle of the longitudinal fissure, between the quadrate lobe in front and the caudate and Spigelian lobes behind (Fig. 716). Through it the portal vein, hepatic artery, and hepatic plexus of nerves enter, and the hepatic ducts and lymphatic vessels leave, the liver, whilst around its margins are attached the two layers of the lesser omentum. The fissure itself is filled, between the entering and issuing vessels, by a loose connective tissue known as Glisson's capsule, which passes with the portal vein into the liver substance.

When the liver is in the body, or when hardened before removal, these three fissures, instead of appearing as wide, shallow depressions, have the form of narrow clefts, with a depth of three-quarters to one inch (18-25 mm.), or even more—a form which results from the folding together of the portions of the liver bounding these fissures.

(4) The **fossa of the gall-bladder** (fossa vesicæ felleæ) is a slight depression which begins (often as a notch) at or near the inferior border of the liver, and runs backwards and to the left, as far as the portal fissure (Fig. 716), separating the quadrate from the rest of the right lobe. Its surface is uncovered by peritoneum as a rule, and in it lies the gall-bladder—the two being united by areolar tissue.

(5) The **fossa of the vena cava** (fossa venæ cavæ) is a deep groove, on the back of the liver, between the Spigelian and right lobes, in which the upper part of the inferior vena cava is embedded, immediately before it pierces the diaphragm. It has been already described in connexion with the posterior area of the parietal surface of the liver, page 1061.

The depressions for the gall-bladder and the vena cava are called, almost indiscriminately, fissures or fossæ. In hardened specimens, it will be seen that only three are really fissure or crevice-like, namely, the umbilical fissure, the portal fissure, and the fissure of the ductus venosus: the remaining two are rather of the nature of fossæ.

Lobes of the Liver.—The liver is divisible into two chief lobes, right and left, which are separated by the attachment of the falciform ligament above and in front, and by the two parts of the longitudinal fissure below and behind. The right lobe forms about four-fifths of the mass of the liver, and on it three secondary lobes—the quadrate, Spigelian, and caudate, already sufficiently described—are marked off by the five fissures referred to in the preceding paragraphs. The left lobe is much smaller and more flattened than the right, and, as a rule, it projects one or two inches (2·5 to 5·0 cm.) to the right of the middle line. The details of these lobes have been already given in connexion with the surfaces of the liver.

Peritoneal Relations of the Liver.—With the exception of (1) the uncovered area at the back of the right lobe, (2) a small triangular space on the parietal surface, where the two layers of the falciform ligament separate posteriorly, and (3) usually, but not invariably, the fossa of the gall-bladder, the liver is completely covered by peritoneum. The covering of the caudate and Spigelian lobes is derived from the small sac, that of the rest of the organ from the great sac of the peritoneum.

The peritoneum of the anterior abdominal wall passes back on the under surface of the diaphragm, whence it is reflected on to the upper aspect of the liver, but the line of reflection is broken by a fold running down at right angles from its middle to the umbilical notch; this is the falciform ligament already referred to. The portion of the reflection to the right of this fold forms the upper layer of the coronary ligament, that to the left forms the upper layer of the left lateral ligament.

Having thus reached the liver from the diaphragm the peritoneum passes forwards, clothing its parietal surface as far as the anterior margin, around which it turns to gain the lower or visceral surface. This it also covers as far back as the portal fissure and the fissure of the ductus venosus (Fig. 716), from which it descends to the stomach as the anterior layer of the lesser omentum.

As regards the covering derived from the small sac:—Its peritoneum passes in through the foramen of Winslow, which is placed immediately beneath the caudate lobe, and thus it clothes this lobe (Fig. 716). Then turning upwards it expands over the Spigelian lobe, clothing its two surfaces.

From the right margin of the Spigelian lobe it is reflected to the diaphragm, here

forming the left boundary (Fig. 724) of the uncovered area of the right lobe, and a third layer of the coronary ligament.

The detailed arrangement of the peritoneum will be found on p. 1046, with the general account of the peritoneal cavity.

Ligaments.—Most of the ligaments of the liver, namely, the coronary, falciform, and two lateral, are formed by folds of peritoneum; the other two, namely, the round ligament and the ligament of the ductus venosus, are remains of fœtal blood-vessels.

The **coronary ligament** (ligamentum coronarium hepatis) consists of the folds of peritoneum which are reflected from the liver to the diaphragm at the margins of the uncovered area of the right lobe; both its upper and lower layers are derived from the great sac. The name of **right lateral ligament** has been given, without sufficient reason, perhaps, to its pointed right extremity (Fig. 716).

The **left lateral ligament** (ligamentum triangulare) is a considerable triangular fold, entirely unconnected with the coronary ligament, which is attached by one end to the upper or parietal surface of the left lobe near its posterior border, and by the other to the diaphragm, for a distance of several inches as a rule.

Its attachment to the diaphragm lies nearly altogether to the left of the œsophageal orifice, and about ¾ inch (18 mm.) in front of the line of this opening. Sometimes it is directed from the diaphragm backwards to its hepatic attachment.

Falciform Ligament (ligamentum falciforme hepatis).—This is also known as the broad and the suspensory ligament, the latter being a distinct misnomer. It is a crescentic fold of peritoneum, which is attached by its convex border to the under surface of the diaphragm, and to the anterior abdominal wall (an inch or more to the right of the middle line) to within a short distance (1 to 2 inches, 2·5 to 5 cm.) of the umbilicus. Its concave border is attached to (the superior and anterior areas of) the parietal surface of the liver; below this it presents a free edge, stretching from near the umbilicus to the umbilical notch of the liver, and containing within it a stout fibrous cord, the round ligament.

Near the back part of the upper aspect of the liver the two layers of which the falciform ligament is composed separate, and leave a triangular area of liver substance in front of the upper end of the vena cava uncovered by peritoneum. Traced backwards, the right layer passes into the upper layer of the coronary ligament, the left into that of the left lateral ligament. It is the remains of the ventral mesentery of the embryo, and probably has no supporting or suspensory action on the liver of the adult.

The **lesser** or **gastro-hepatic omentum** (omentum minus) is a fold of peritoneum which extends from the liver to the lesser curvature of the stomach. Of its two layers—which are largely blended together in the adult—the anterior is derived from the great, the posterior from the small sac.

It is attached above to the margins of the portal fissure, and also to the bottom of the fissure of the ductus venosus. Below, it is connected to the lesser curvature of the stomach, where its two layers separate to enclose that organ, and also to the upper border of the duodenum for an inch or more beyond the pylorus. Between its layers, close to its right or free border, are contained the bile duct, the hepatic artery, the portal vein, and the nerves and lymphatics passing to the portal fissure (Fig. 718). It is wide in the middle and narrow at each end. Of the two ends the right is free, and stretches from the liver to the duodenum, forming the anterior boundary of the foramen of Winslow. The left end is very narrow, and is attached to the diaphragm between the œsophageal and caval openings (just to the right of the reference line in Fig. 724, marked "top of small sac.")

The portion of the omentum passing between the liver and the stomach is sometimes known as the hepato-gastric ligament (ligamentum hepato-gastricum), that between the liver and the duodenum as the hepato-duodenal ligament (ligamentum hepato-duodenale).

The **round ligament** (ligamentum teres hepatis) is a stout fibrous band which passes from the umbilicus backwards and upwards, within the free margin of the falciform ligament, to the umbilical notch of the liver, and thence back in the umbilical fissure, to join the left branch of the portal vein. It is the remains of the umbilical vein which, before birth, carries the arterial blood from the placenta to the body of the fœtus (Fig. 717).

The **remains of the ductus venosus** (ligamentum venosum Arantii) is a slender fibrous bundle, which passes from the left branch of the portal vein, nearly opposite the attachment of the round ligament, backwards in the fissure bearing its name, to be connected with the inferior vena cava as it leaves the liver. In the fœtus this structure is a considerable vessel, which conveys some of the blood brought to the portal fissure by the

umbilical vein directly backwards to the vena cava. At the time of birth the ductus venosus and umbilical vein cease to carry blood, their cavities become obliterated, and they degenerate into fibrous cords.

Physical Characters of the Liver.—The liver is a compact mass, moderately firm to the touch; it is pliant, but not tough, and is easily lacerated. Its torn surface presents a granular appearance, due to the fact that it is made up of small lobules about the size of a pin's head ($\frac{1}{12}$th to $\frac{1}{25}$th of an inch, 1 to 2 mm.). These little lobules also give its exterior a characteristic finely-mottled appearance. Its colour is reddish brown, and its specific gravity varies from 1·05 to 1·06.

In the Child.—The liver of the child differs from that of the adult, in being relatively larger—$\frac{1}{18}$th of the body weight at birth as against $\frac{1}{36}$th or $\frac{1}{40}$th in the adult—in occupying more of the abdominal cavity, and in the fact that its two lobes are more nearly equal in size, the proportion being as two to one at birth and as four to one in the adult.

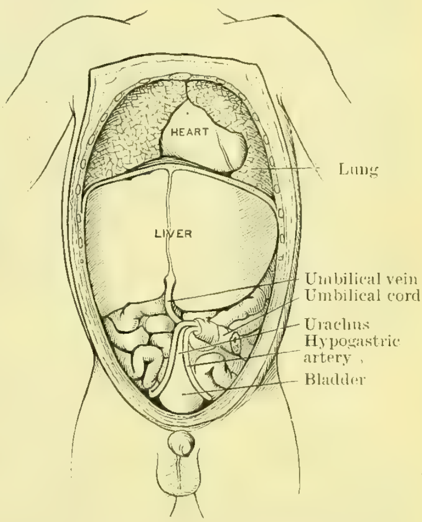


Fig. 717.—The Abdominal and Thoracic Viscera of a Five-Months Fœtus.
The large liver and the large size of its left lobe, at this age, should be noted.

Variations in Size, Form, and Position.—Few organs will be found to vary more in **size** in different bodies than the liver; these variations, however, are very frequently to be looked upon as pathological. But even normal, healthy livers vary in weight from 48 to 58 ounces in the adult male, and from 40 to 50 ounces in the female.

Variations in form and **position** doubtlessly take place physiologically, as a result of the conditions of fulness or emptiness of the adjacent viscera; for, though the liver, like the other solid abdominal organs, has an intrinsic shape of its own, this is capable of modification within certain limits by the varying pressure of the surrounding parts. Thus, great distension of the stomach, or of a portion of the transverse colon lying in the stomach chamber, pushes the liver over to the right, so that it may hardly reach the middle line, and at the same time it increases its vertical depth. On the other hand, a distended state of the small intestines, with a contracted stomach and colon, may have the opposite effect, flattening it from below upwards and enlarging it in the transverse direction.

Variations in form and position *due to malformations* of the thoracic framework, either congenital or acquired, are very common, particularly in females as a result of tight lacing, which carries in the lower ribs. Sometimes in these cases the constriction of the waist lies chiefly below the liver. The organ is then forced up against the diaphragm, filling its whole vault, and extending across to the left abdominal wall, where its left margin may lie in the interval between the diaphragm and the spleen. But more commonly it would seem that the liver is caught by the constriction: its upper part is then closely pressed into the vault of the diaphragm, which, owing to the narrowing of the thorax, is unable to accommodate the whole organ, so that its lower part is crushed down for a considerable distance into the umbilical zone of the abdomen (Fig. 678, p. 1006), particularly on the right side. Often, too, a wide, tongue-like process (the so-called "Riedel's lobe") descends from the lower margin, external to the gall-bladder. This process, which when very large may reach to the iliac crest, is sometimes found in men, although more common in women, and is liable to be mistaken for a tumour. A somewhat similar process occasionally descends from the left lobe.

Again, in apparently healthy bodies the liver may extend up on the right side almost to the fourth rib; whilst in other cases it may be as low as the sixth rib, or even lower. Nor is it rare—particularly in females—to find the lower border projecting two or three inches (5·0 to 7·5 cm.) below the margin of the thorax on the right side (Fig. 678, p. 1006).

Reference should be made here to certain grooves often seen on the liver. Some of these are found running obliquely low down at the right side where the liver is in contact with the ribs; they are particularly common in females, and are due to the pressure of the ribs resulting from tight lacing. Grooves of a different kind are found at the upper part of the parietal surface, where the liver is in contact with the diaphragm; these usually run radially, that, is in the direction of the muscular fibres of the diaphragm, and are apparently produced by a wrinkling, or irregular contraction, of the diaphragm. At least, ridges of the diaphragm are found lying in the grooves, and these ridges or wrinkles would seem to be responsible for the production of the grooves.

Finally, the liver may present certain **congenital irregularities** in the direction of additional fissures and lobes, which reproduce the conditions found in the higher apes, and are very

commonly present in the fœtus (Thomson). Or the liver may be divided up into a large number of distinct lobes, as in most other animals.

Changes in position have been already referred to in connexion with variations in form; there need only be added here that the liver ascends and descends at every expiration and inspiration respectively, and that it also descends, but very slightly, in changing from the reclining to the erect posture. Occasionally, without any evident cause, the liver and diaphragm are found to occupy a higher or lower position than usual.

Fixation of the Liver.—At first sight it is not easy to understand the means by which the liver maintains its position in the abdomen (and the same remark applies, perhaps, to other solid abdominal organs). The falciform ligament probably gives it no support, as it is quite lax when in the body. Nor can it be said that its vessels, except perhaps the hepatic veins, assist. However, on considering the conditions under which the viscera are placed in the abdominal cavity the problem becomes less difficult.

The abdomen is a closed cavity, with a firm framework to its upper part, a tightly stretched diaphragm for its roof, and muscular walls all round. Into the concavity of this roof the parietal surface of the liver is fitted with perfect accuracy, so that the two are in absolute contact, and cannot be separated without producing a vacuum, unless some other structure is in a position to fill the space. But there is hardly any other viscus movable enough to pass up over the front of the liver into the vault of the diaphragm, so that atmospheric pressure alone is probably sufficient to retain the organ *in situ*, as in the case of the hip joint. In addition, the abdominal muscles are always in a condition of tonic contraction or "tone," which gives rise to an intra-abdominal pressure. This is effective in all directions, and consequently there is a considerable pressure on all the abdominal walls. The liver, being in absolute contact with the roof, may be considered a part of this wall, and it is consequently affected by this pressure which helps to sustain it. Add to this, the support which the organ receives from the intestines, the stomach, and the pancreas; from the coronary and lateral ligaments; from the connexion of the back of the right lobe by areolar tissue to the diaphragm; and, finally, from the vena cava embedded in the liver and sending its hepatic veins forwards to all parts of the organ, just before the cava itself is firmly attached to the margins of the caval orifice in the central tendon of the diaphragm, and we will probably find sufficient cause for the maintenance of the organ in its position in the abdominal cavity.

THE GALL-BLADDER AND BILE-PASSAGES.

Under this heading we have to consider the hepatic ducts, the gall-bladder, the cystic duct, and the common bile-duct.

The **excretory ducts** of the liver (Fig. 718) begin within the hepatic lobules as minute channels, running between the hepatic cells (Fig. 721), and known as the **bile canaliculi** (ductus biliferi).

Outside the lobules these join (Fig. 721) the **interlobular ducts** (ductus interlobulares), which latter by uniting form larger and larger ducts, and finally end in two, or more, chief hepatic ducts, a larger from the right, and a smaller from the left lobe, which unite immediately after leaving the liver to form the hepatic duct.

As a rule, five or six ducts leave the liver at the bottom of the portal fissure; these generally unite into right and left main ducts; sometimes they all converge towards, and unite at the beginning of the hepatic duct. It is interesting to note that the ducts from the Spigelian and caudate lobes join the left main duct.

The **hepatic duct** (ductus hepaticus), formed at the bottom of the portal fissure by the union of right and left chief ducts (Fig. 718), passes downwards, with an irregular course, and, just outside the mouth of the portal fissure, is joined by the cystic duct (Fig. 718) to form the common bile-duct. In length it usually measures about 1 to $1\frac{1}{4}$ inches (25 to 31 mm.), and in breadth, when flattened out, nearly $\frac{1}{4}$ inch (6 mm.), or about as much as a goose quill. It lies, practically altogether, within the portal fissure.

The **gall-bladder** (vesica fellea), with its cystic duct, may be looked upon as a diverticulum of the bile-duct, enlarged at its extremity to form a reservoir for the bile. It is pear-shaped, and lies obliquely on the under surface of the liver (Fig. 718). The wide end, or **fundus**, usually reaches the inferior border of the liver—where there is sometimes a notch to receive it—and comes in contact with the anterior abdominal wall (Fig. 714). The **body** (corpus) runs backwards, upwards, and to the left, lying in the fossa of the gall-bladder, and near the portal fissure passes rather abruptly into the narrow neck. The **neck** (collum) is curved inwards towards the portal fissure, in the form of the italic letter *s*, and when distended it presents the appearance of a spiral constriction which is continued into the beginning of the

cystic duct, and is due to a series of crescentic folds placed somewhat spirally round the interior of its cavity. Having arrived near the portal fissure, much reduced in size, it passes into the cystic duct.

As a rule the gall-bladder is covered by the peritoneum of the inferior surface of the liver, except on its upper aspect, which is united to the fossa of the gall-bladder by areolar tissue. Sometimes, but rarely, this surface is covered also, and the gall-bladder is then suspended from the liver by a short peritoneal ligament. The fundus usually lies in contact with the anterior abdominal wall, at or immediately beneath the point where the right Poupart line strikes the lower margin of the ribs (*i.e.* in the angle between the outer border of the right rectus muscle and the lower margin of the ribs). *Above*, the gall-bladder lies against the liver; and *below*, it rests on the transverse colon in front, and behind, near its neck on the duodenum.

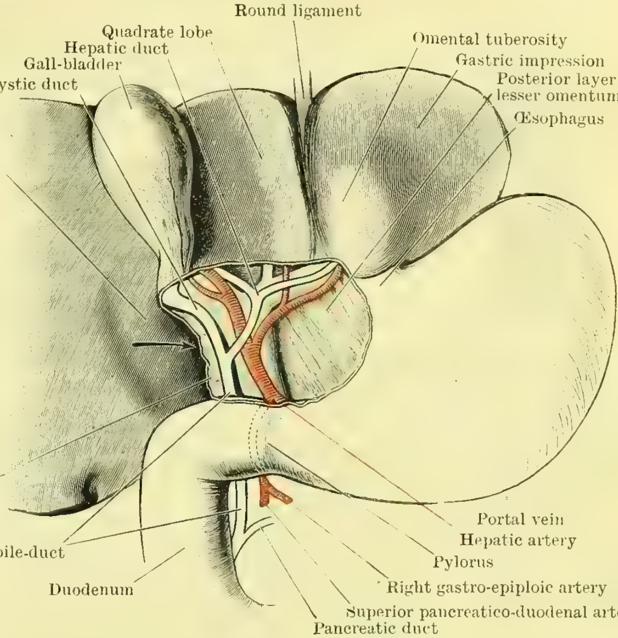


FIG. 718.—STRUCTURES BETWEEN THE LAYERS OF THE LESSER OMENTUM.
The liver has been raised up, and the anterior layer of the omentum removed (semi-diagrammatic).

In some bodies the fundus of the gall-bladder does not reach the border of the liver or the abdominal wall. In others it may be moved considerably to the right of the Poupart line—possibly as a result of distension of the stomach and colon—or as a result of tight lacing, it may be moved to the left, and may then lie near the middle line and far below the ribs (Fig. 678, p. 1006).

Its total absence, as well as the presence of two distinct gall-bladders, and several other irregularities in form, have been recorded.

Its *size* is usually about 3 inches (75 mm.) in length, and 1 to $1\frac{1}{4}$ inch (25 to 31 mm.) in diameter. Its capacity varies between 1 and $1\frac{1}{2}$ fluid ounces.

Structure of Gall-bladder.—The wall of the gall-bladder is composed of an outer coat of peritoneum, usually incomplete; a middle coat of fibrous tissue with unstriped muscle intermixed; and an inner coat of mucous membrane, which is covered by columnar epithelium, and is raised into a number of small ridges, which confer on it a reticulated appearance. The mucous membrane is always deeply stained with bile when the gall-bladder is opened after death.

The **cystic artery** which supplies it with blood arises from the hepatic, or its right division, and divides into two branches, which run on the lateral surfaces of the organ. The **veins** join the portal trunk, and the **nerves** come from the sympathetic on the hepatic artery.

The **cystic duct** (ductus cysticus), about half the diameter of the hepatic duct (3 mm.), but usually slightly longer ($1\frac{1}{4}$ to $1\frac{1}{2}$ inch, 31 to 37 mm.), begins at the neck of the gall-bladder, and running an irregular course backwards and inwards, joins the hepatic duct at the mouth of the portal fissure, to form the common bile-duct. The spiral constriction found in the neck of the gall-bladder is continued into the beginning of this duct.

The **common bile-duct** (ductus choledochus) begins at the mouth of the portal fissure, where it is formed by the union of the hepatic and cystic ducts. From this it passes downwards, in front of the foramen of Winslow, lying between the

two layers of the lesser omentum, with the portal vein behind and the hepatic artery to its left. It next descends behind the first part of the duodenum (Fig. 718), and then between the pancreas and descending duodenum. Finally, it meets the pancreatic duct, and the two, running together, pierce the inner wall of the descending duodenum very obliquely, and open by a common orifice on the bile papilla (papilla duodenalis), about $3\frac{1}{2}$ or 4 inches (8·7 to 10 cm.) beyond the pylorus (see p. 1019).

The length of the common bile-duct is about 3 inches (75 mm.), and its diameter, which is very variable, is generally about $\frac{1}{4}$ inch (6 to 7 mm.).

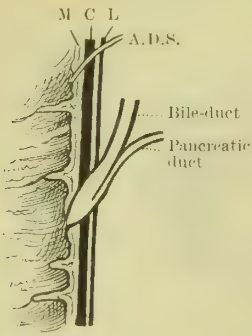


Fig. 719.—Diagram showing the Bile and Pancreatic Ducts piercing the Wall of the Duodenum obliquely.

ADS, Accessory pancreatic duct (of Santorini); C, Circular muscular fibres; L, Longitudinal muscular fibres; M, Mucous coat.

Structure of Excretory Ducts.—With the exception of the peritoneal coat, which is absent, the hepatic, cystic, and common bile-ducts, agree with the gall-bladder in general structure.

The bile and pancreatic ducts, in piercing the wall of the duodenum, run obliquely through its coats for about $\frac{1}{2}$ or $\frac{3}{4}$ of an inch (12 to 18 mm.), and, as a rule, do not unite until they have almost reached the opening on the bile papilla (Fig. 719). This orifice is very much smaller than either duct, and the short and relatively wide common cavity which precedes it is sometimes known as the "ampulla of Vater." Occasionally the cystic and hepatic ducts open into the duodenum separately. Sometimes, too, the cystic duct joins the right hepatic duct instead of the hepatic duct proper.

Vessels of the Liver.

The liver derives its blood-supply from two sources, namely—(1) the **portal vein**, which conveys to it, for further elaboration, the blood from the digestive system, laden with the products of digestion; and (2) the **hepatic artery**, which supplies it with blood for the nourishment of its own tissue. All the blood is returned from the liver to the inferior vena cava by the **hepatic veins**.

The **portal vein** and the **hepatic artery** pass up to the liver between the two layers of the lesser omentum and in front of the foramen of Winslow. Here they are accompanied by the hepatic duct, which lies to the right, whilst the artery is placed to the left, and the portal vein behind both. In this order they enter the portal fissure, and there becoming re-arranged, so that the vein lies behind the artery in the middle and the duct in front, each breaks up into two chief branches—a right and a left—and several smaller ones, which enter the liver substance, surrounded by a prolongation of the connective tissue coat of the liver, known as Glisson's capsule. Within the organ the three vessels run and divide together, so that every branch of the portal vein is accompanied by a corresponding (but much smaller) branch of the hepatic artery and of the hepatic duct: and the three, surrounded by a prolongation of Glisson's capsule, and accompanied by branches of the hepatic nerves and lymphatics, run in special tunnels of the liver substance, which are known as **portal canals** (Fig. 720, B).

Finally, the portal vein breaks up into **interlobular veins** (venæ interlobulares) which lie in the spaces between the liver lobules (Fig. 721). The branches of these enter the lobules on all sides, and unite with their capillary network, which converges towards the centre of the lobule, and joins the intralobular or central vein (vena centralis).

The hepatic artery similarly divides into **interlobular branches** (rami arteriosi interlobulares) of a very small size, which accompany the interlobular branches of the vein, and supply the tissue and the vessels between the lobules. In addition, the hepatic artery gives off **vaginal branches** to supply the walls of the vessels and ducts, and the connective tissue in the portal canals; and **capsular branches**, which are distributed to the fibrous coat of the liver.

The **hepatic veins** are two large and several small veins, which converge from the different portions of the liver (Fig. 720, A) to the vena cava. Their ultimate radicles are the intralobular or central veins, which run down through the centre of the liver lobules, and passing out at the base, join the **sublobular veins**: these by their union finally form the hepatic veins. The two chief hepatic veins, which are of very large size, open into

the vena cava, as it leaves the liver, and immediately before it pierces the diaphragm. The smaller branches open into it lower down. The branches of the portal differ from those of the hepatic vein in the following points:—(1) The branches of the portal vein converge towards the portal fissure; those of the hepatic veins towards the vena cava. (2) On section of the liver the portal branches are always seen to be accompanied by branches of the hepatic artery and duct, whilst those of the hepatic vein run alone; and (3) owing to the loose wrapping of connective tissue (Glisson's capsule) which surrounds the branches of the portal vein, their walls fall away from the liver substance when empty, and collapse, whilst the hepatic veins, which are destitute of this wrapping, are closely connected to the liver substance, and consequently do not collapse so easily as the portal vessels.

The **lymphatics** of the liver are arranged in a superficial and a deep set:—1. The **superficial set** lies beneath the peritoneum on both (*a*) the visceral and (*b*) the parietal surfaces of the organ. (*a*) The vessels from the *visceral surface* pass chiefly to the hepatic glands, which lie between the layers of the lesser omentum; but some of them, from the back part of this surface on the right lobe, join the lumbar glands, and others from the back part of the left lobe, go to the cœliac glands. (*b*) The vessels from the *parietal surface* pass in various directions. Those from the adjacent parts of the right and left lobes pass up in the falciform ligament, and pierce the diaphragm to reach the anterior mediastinal glands, and end finally in the right lymphatic duct. Those from the anterior part of this surface pass down to the inferior aspect, and join the hepatic glands in the lesser omentum. The lymphatics from the back of the right lobe pierce the diaphragm between the layers of the coronary ligament, and join some glands in the thorax around the upper end of the inferior cava; others run in the right lateral ligament, and either pierce the diaphragm and end in the anterior mediastinal glands, or, turning down, join the cœliac group.

2. The **deep lymphatics** accompany either (*a*) the portal or (*b*) the hepatic veins. (*a*) The former set pass out through the portal fissure and join the hepatic glands, the efferent vessels of which join the cœliac glands. (*b*) Those which accompany the hepatic veins pierce the diaphragm with the vena cava, and having formed connexions with the group of glands at its upper end, within the thorax, turn down and join the beginning of the thoracic duct.

The **nerves**, which are chiefly of the non-medullated variety, are derived from the left pneumogastric and the solar plexus of the sympathetic. The branches of the former pass from the front of the stomach up between the layers of the lesser omentum to the liver. Those of the latter pass from the cœliac plexus along the hepatic artery—forming the hepatic plexus—to the portal fissure, where they enter the liver with the blood-vessels. They are distributed chiefly to the walls of the vessels and of the bile-ducts.

Structure of the Liver.

The liver is invested by an outer **serous coat** (tunica serosa), already described in connexion with the peritoneum. Within this is a thin **areolar coat** (capsula fibrosa Glissonii) of delicate fibrous tissue, which is most evident where the serous coat is absent. In the neighbourhood of the portal fissure it is particularly abundant, and here, under the name of **Glisson's capsule**, it surrounds the vessels entering the fissure, and accompanies them through the portal canals in the liver substance. This coat is continuous with the fine areolar tissue which pervades the liver, surrounding its lobules and holding them together.

The liver substance proper is made up of an enormous number of small lobules, $\frac{1}{12}$th to $\frac{1}{25}$th inch (1 to 2 mm.) in diameter, closely packed, and held together by a small amount of connective tissue. In man the lobules are not completely separated from one another all round their circumference, but coalesce in places; the reverse is the case in certain animals. These lobules are arranged around the branches of the hepatic veins, to form the compact mass of the liver, in the following manner:—

The hepatic veins radiate from the inferior vena cava, at the back of the liver, to all parts of the organ, dividing and re-dividing until the vessels are reduced to branches of a very small size, known as **sublobular veins**—the whole arrangement may be aptly compared so far to the branching of a tree (Fig. 720, A). On all sides there open into these sublobular veins numerous closely-crowded vessels—the **intralobular or central veins** (which, following our simile, may be compared to an enormous number of thorns growing out on all sides from the sublobular twigs of the tree). On each of these little central veins there is impaled, as it were, a **lobule** (which is more or less like a conical bullet in shape—Purser). These little conical lobules, with their intralobular or central veins running through them, are so numerous and so closely packed together, that they give rise to the practically solid liver tissue.

As regards the **veins**: The lobules are surrounded by the interlobular branches of the portal vein, from which numerous twigs enter the lobule on all sides, and converging,

join the central or intralobular vein (Fig. 721). This runs down through the centre of the lobule (Fig. 720, A), and opens at its base into a sublobular vein. The sublobular veins, uniting and growing larger by constant additions, finally form the hepatic veins, which open into the vena cava.

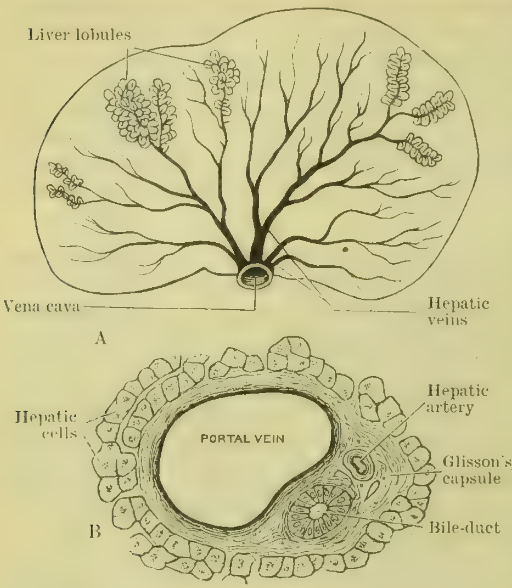


Fig. 720.—Diagrams illustrating the Structure of Liver.

A, Arrangement of liver lobules around the sublobular branches of the hepatic vein; B, Section of a portal canal, showing its contained branches of the portal vein, hepatic artery, and bile-duct, surrounded by a prolongation of Glisson's capsule.

Hepatic Cells.—In the intervals between the branches of the capillaries, running from the interlobular to the intralobular veins (Fig. 721), are placed the polygonal-shaped, epithelial, hepatic cells. Between the cells run the **bile canaliculi** (ductus biliferi) which, passing out of the lobule (Fig. 721), join the **interlobular bile-ducts** (ductus interlobulares), and these uniting, finally end in the hepatic ducts.

Development of the Liver.

In man, the liver first appears as two hollow outgrowths from the ventral wall of the foregut, in the position of the future duodenum. These outgrowths, which are formed entirely of entoderm (hypoblast), pass forward and upward into a mass of mesodermic tissue—called by His the **septum transversum**—which lies in front of the foregut just below the heart. In addition to constituting the mesodermic bed in which the liver is developed, this mass also forms the chief rudiment of the future diaphragm; through it, too, pass the great fœtal veins on their way to the heart.

The two outgrowths give off numerous solid buds of endodermic cells—known as **hepatic cylinders**—which grow into the tissue of the septum transversum, and there

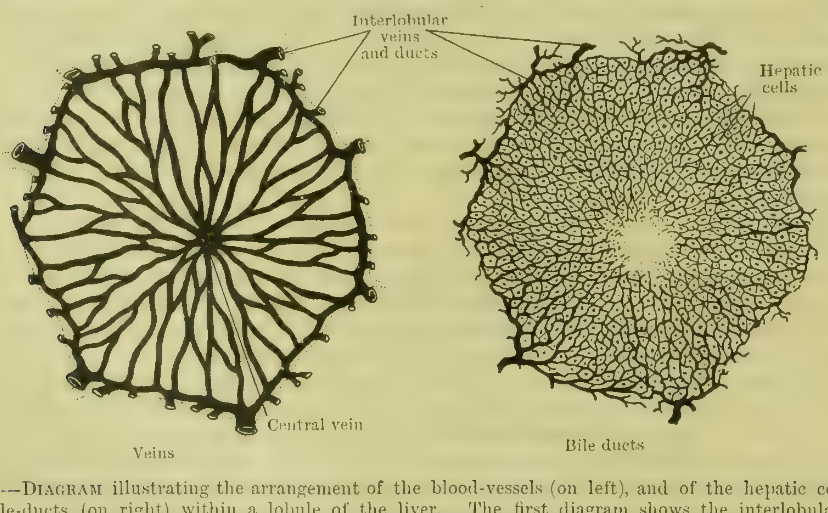


Fig. 721.—Diagram illustrating the arrangement of the blood-vessels (on left), and of the hepatic cells and bile-ducts (on right) within a lobule of the liver. The first diagram shows the interlobular veins running around the outside of the lobule, and sending their capillaries into the lobule to join the central vein. In the second diagram the bile capillaries are seen, with the hepatic cells between them, radiating to the periphery of the lobule, where they join the interlobular bile-ducts.

branch and anastomose freely with one another, forming a complicated network, the meshes of which are occupied by blood-vessels. From the sides of these primary hepatic cylinders come off secondary cell buds, which similarly branch and anastomose; and this process is continued until the mass of the liver is formed.

The two original outgrowths which open into the foregut close together, are soon succeeded by an evagination of the wall of the duodenum, which embraces the orifices of both, and subsequently forms the common bile duct; whilst the two primary diverticula, which are now connected with the evagination, form the right and left hepatic ducts.

The interlobular bile ducts and the bile capillaries are formed by a canalisation of the primitive hepatic cylinders which have been budded off from the original diverticula. And the gall-bladder is formed as an outgrowth from the common bile duct.

As the liver increases in size, it begins to project down from the septum transversum into the abdominal cavity, so that now, instead of being situated within the septum, it looks like an appendage of its under surface. In other words, the septum begins to differentiate into two parts—a lower, the liver, and an upper, which constitutes the greater portion of the diaphragm, both of these having been at first one continuous mass. In the course of development the separation of the two becomes more marked, and finally is complete everywhere except at the coronary and lateral ligaments behind, and at the falciform ligament in front, where they are still connected.

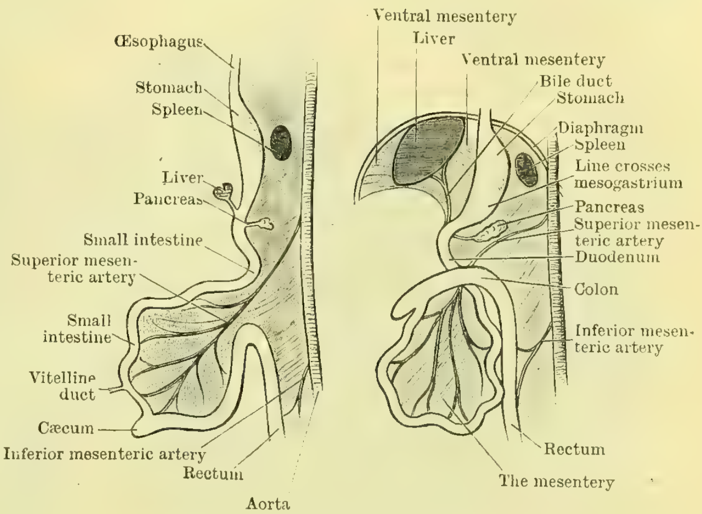


Fig. 722.—Two Diagrams to illustrate the Development of the Intestinal Canal.

The figure to the right shows the rotation of the intestinal loop round the superior mesenteric artery. In both figures the parts are supposed to be viewed from the left side.

As the liver separates off from the future diaphragm, and descends into the abdomen, there descends with it the **ventral mesentery**—a fold which connects the stomach and duodenum with the anterior abdominal wall. This is divided by the liver into two parts—a posterior, stretching from the front (lesser curvature) of the stomach to the liver, which becomes the lesser omentum; and an anterior, stretching from the liver to the anterior wall of the abdomen, which forms the falciform ligament.

In early fœtal life the liver is relatively of enormous size. Up to the fourth or fifth month it almost completely fills the abdominal cavity, leaving but a small space below for the intestines. Subsequently its relative size is not so great; but even at birth it still occupies nearly half of the abdomen, and forms about $\frac{1}{18}$th of the body weight, whilst in the adult it is reduced to $\frac{1}{40}$th. At first the right and left lobes are nearly equal in size; subsequently, the right grows more rapidly than the left, so that at birth it is about twice, and in the adult four times, as large as the left. In the fœtus, and at birth, the caudate and Spigelian lobes are relatively larger than in the adult.

The changes which take place during development in the vessels connected with the liver are described on page 884.

THE PANCREAS.

The **pancreas** is an elongated glandular mass which lies transversely on the posterior abdominal wall, with its right end resting in the concavity of the duodenum (Fig. 723), and its left end touching the spleen. It secretes a digestive fluid—the pancreatic juice—which is conveyed to the duodenum by the *pancreatic duct*, and constitutes one of the chief agents in proteid digestion.

The absence of a true capsule, and the resulting distinct lobulation of the gland, give the pancreas a very characteristic appearance (Fig. 723).

Position.—The greater part of the gland lies in the epigastrium, but the tail and adjacent part of the body extend into the left hypochondrium.

The head is placed opposite the second and upper part of the third lumbar vertebra, whilst the body runs to the left, about the level of the first lumbar vertebra. It should be added, that very often the lower portion of the head projects some distance below the subcostal plane, and thus lies in the umbilical region.

In **shape** the pancreas, when hardened *in situ*, is very irregular (Fig. 723), its right end being flattened and hook-like, whilst the rest of the organ is prismatic and three-sided. It may, perhaps, in general form be best compared to the letter J placed thus ⊂, particularly if the stem and hook of the letter be thickened.

The gland is divisible into a head, a neck, and a body. The **head** corresponds to the hook of the ⊂, and runs downwards and to the left along the second and third portions of the duodenum. The stem of the ⊂ represents the **body** of the gland, and the narrow part connecting the two is the **neck**.

When removed from the body without previous hardening, the pancreas loses its true form, and becomes drawn out into a slender, elongated, tongue-shaped mass, with a wider end turned towards the duodenum, and a narrow end corresponding to the tail.

Its total *length*, when fixed *in situ*, is about 5 or 6 inches (12·5 to 15 cm.); after removal, if not previously hardened, it is easily extended to a length of 8 inches (20 cm.).
Its *weight* is usually about 3 ounces (87 grammes).

Relations.—The general position and relations of the pancreas may be briefly expressed as follows:—The head (Fig. 723) lies in the concavity of the duodenum, with the vena cava and aorta behind it; the body crosses the left kidney and suprarenal capsule; and the tail touches the lower part of the spleen. The greater part of the organ lies behind the stomach, which must be detached from the great omentum, and turned upwards, in order to expose it.

In describing the detailed relations, each part of the organ will require to be considered separately.

The **head** (caput pancreatis) is the large flattened and somewhat disc-shaped portion of the gland which lies in the concavity of the duodenum, extending along its second and third portions almost as far as the duodeno-jejunal flexure. *Above*, in its right half, it is continuous with the neck; whilst to the left of this it is separated from the neck by a deep notch (incisura pancreatis), in which lie the superior mesenteric vessels (Fig. 723). Its *right* and *lower borders* are moulded on to the side of the duodenum, which lies in a groove of the gland substance—the common bile duct being interposed as far down as the middle of the second portion of the duodenum. The *posterior surface* of the head is applied to the front of the inferior vena cava; it also lies on the renal vessels, and, at its left end, on the aorta as well. Its *anterior surface* is in contact above and on the right with the beginning of the transverse colon (Fig. 724), without the interposition of the peritoneum as a rule. Below this it is clothed by peritoneum, and is covered by the small intestine.

The **superior mesenteric vessels**, after passing forward through the pancreatic notch, descend in front of that portion of the head (processus uncinatus) which runs to the left along the third part of the duodenum. The **superior pancreatico-duodenal vessels** run downwards, and break up on the front of the head (Fig. 723).

The **neck** (Fig. 723) is a comparatively attenuated portion of the gland which lies in front of the portal vein, and connects the head to the body. Springing from the upper and right portion of the head, it runs upwards and to the left for about 1 inch (25 mm.), and then passes into the body.

The neck is about $\frac{3}{4}$ inch (18 mm.) in width, and less than $\frac{1}{2}$ inch (12·5 mm.) in thickness. *In front and to its right* lie the first part of the duodenum and the pylorus; *behind and to the left* it rests upon the beginning of the portal vein, which is formed under cover of its lower border, by the union of the splenic and superior mesenteric veins. It has a partial covering of peritoneum on its anterior surface; and its beginning is generally marked off from the head by the gastro-duodenal artery, with its continuation the superior pancreatico-duodenal, which lies in a groove of the gland substance between the head and neck.

The neck, which was first described by Symington, forms as distinct and definite a division as any other portion of the gland.

The **body** is of a prismatic form, largest where it lies in front of the left kidney, and usually somewhat tapering towards the tail (Fig. 724). Beginning at the termina-

tion of the neck, it runs backwards and to the left across the front of the left kidney, beyond which its extremity or tail comes in contact with the spleen. When hardened *in situ* it presents three surfaces — superior, inferior, and posterior — all of which are of nearly equal width (namely, about $1\frac{1}{4}$ inch : 31 mm.).

The **upper surface** (facies anterior) is widest towards the left end; it looks upwards

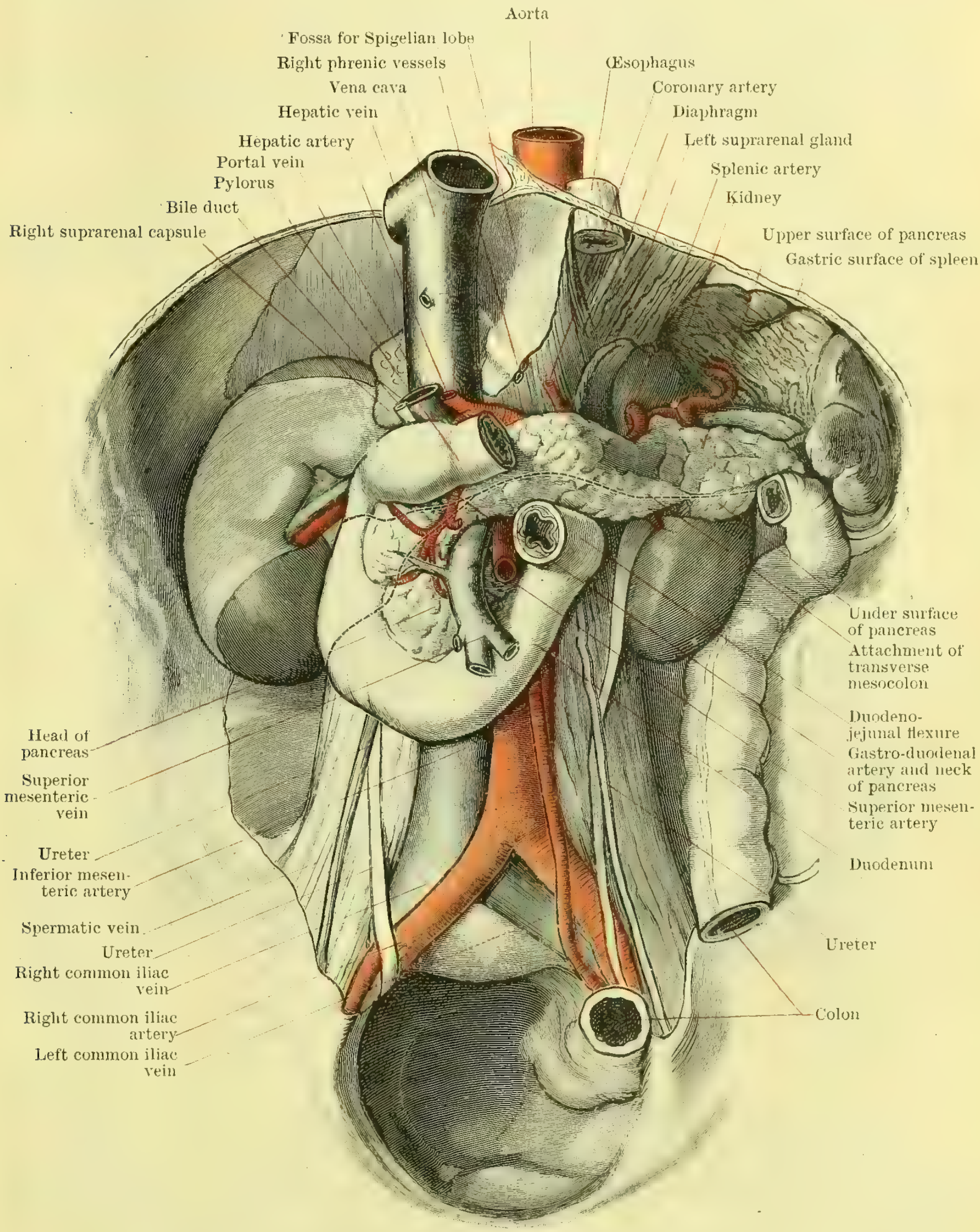


Fig. 723.—The Viscera and Vessels on the Posterior Abdominal Wall.

The stomach, liver, and most of the intestines have been removed. The peritoneum has been preserved on the right kidney, and the fossa for the Spigelian lobe. In taking out the liver, the vena cava was left behind. The stomach-bed is well shown. (From a body hardened by chromic-acid injections.)

and forwards (Fig. 723), and forms a considerable portion of the stomach-bed. This surface is completely covered by peritoneum, derived from the posterior wall of the small sac, which latter separates the pancreas from the under surface of the stomach. Towards its right extremity it presents an elevation or prominence where the body joins the neck. This projects against the back of the small omentum when the stomach is distended, and is consequently known as the **omental tuberosity** (tuber omentale).

The **inferior surface of the body**, which, like the superior, is, as a rule, widest towards its left end, looks downwards and slightly forwards. It is completely covered by peritoneum, viz. the descending layer, derived from the transverse mesocolon (Fig. 724). It lies in contact with the duodeno-jejunal flexure towards its right end, with the splenic flexure of the colon near its left end, and with a mass of small intestine (jejunum, which is always found packed in beneath it) in the rest of its extent.

The **posterior surface of the body** looks directly backwards, and is entirely destitute of peritoneum. It is connected by areolar tissue to the posterior abdominal wall with the organs lying upon it. From right to left these are: the aorta with the origin of the superior mesenteric artery, the left renal vessels, the left suprarenal capsule, and the left

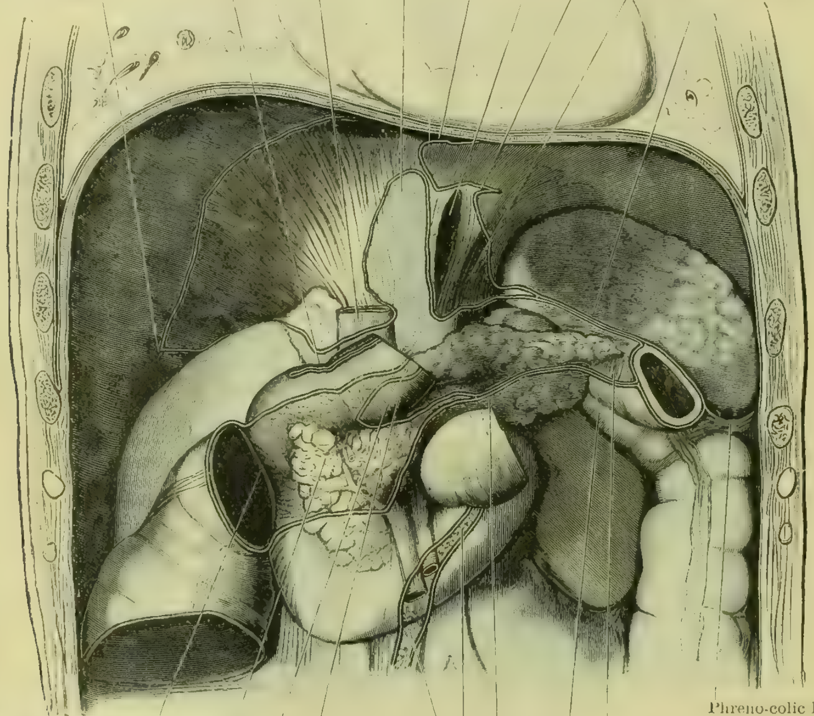


FIG. 724.—THE PERITONEAL RELATIONS OF THE DUODENUM, PANCREAS, SPLEEN, KIDNEYS, ETC.

kidney. In addition, the splenic artery runs its tortuous course to the left behind the upper border of the pancreas, whilst the splenic vein runs, behind the gland, at a lower level than the artery.

The three surfaces of the body of the pancreas are separated by three borders. The **anterior border** is the most prominent, and gives attachment to the transverse mesocolon (Fig. 724). It is, as it were, squeezed forward, by the pressure of the stomach above and the small intestine below, into the interval between these two sets of viscera, thus following the line of least resistance (Cunningham). Towards the neck this border is no longer prominent, but becomes rounded off, so that here the upper and lower surfaces are confluent.

The cœliac axis projects over the **upper border**, and sends its hepatic branch to the right, resting upon it, whilst the splenic artery runs to the left behind it (Fig. 723). The **inferior border** calls for no special description.

The **tail of the pancreas** is the somewhat pointed left end of the body, which is in

contact with the lower portion of the gastric surface of the spleen. It usually presents an abrupt, blunt ending, in which case it is related to the spleen in the manner just described; or it may be elongated and narrow, when it bends backwards around the outer aspect of the kidney, and beneath the base of the spleen. In either case it lies in contact below with the splenic flexure of the colon (Fig. 723).

Peritoneal Relations of the Pancreas.—The posterior surface of the pancreas is entirely free from peritoneum. The other surfaces derive their peritoneal covering from the prolongation of the two layers of the transverse mesocolon, which latter is attached to the anterior border of the gland, from the tail to the neck. At this border the two layers separate (Fig. 707, p. 1048), the anterior—derived from the small sac—passing backwards and upwards over the superior surface; the posterior—derived from the large sac—turning downwards and backwards along the inferior surface.

As the transverse mesocolon is followed to the right it ceases, as a rule, that is, its two layers fail to meet about the neck of the pancreas (Fig. 724). Beyond this the posterior surface of the colon is generally free from peritoneum, and is connected by areolar tissue to the front of the head of the gland. Below the level of the colon the head is covered by the continuation downwards of the peritoneum from the under surface of that gut. Often, however, the transverse mesocolon is continued to the right as far as the hepatic flexure, when the anterior surface of the head is then completely covered by peritoneum.

Ducts of the Pancreas.—Almost invariably two ducts are found in the interior of the pancreas—the **pancreatic duct** proper and the **accessory pancreatic duct.**

The **pancreatic duct** (ductus pancreaticus Wirsungi) begins near the tip of the tail by the union of small ducts from the lobules forming that part of the organ. From this it pursues a rather sinuous or zigzag course (Fig. 725) through the axis of the gland, at first running transversely to the right, until the neck is reached, then bending downwards towards the head. Here it approaches the second portion of the duodenum, and meeting the bile duct, the two pierce the inner wall of the gut obliquely (for $\frac{1}{2}$ to $\frac{3}{4}$ of an inch, 12 to 18 mm.), and open, by a common orifice on the bile papilla, about $3\frac{1}{2}$ or 4 inches (8·7 to 10 cm.) beyond the pylorus (see p. 1070).

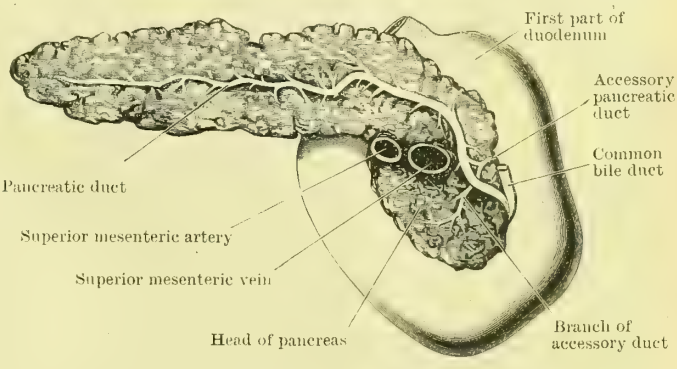


FIG. 725.—THE PANCREAS AND DUODENUM FROM BEHIND, with the pancreatic duct exposed.

The superior mesenteric vessels are also shown in section, passing forward, surrounded by the recurved portion of the head of the pancreas.

In its course through the gland the duct receives numerous branches, which join it, as a rule, at very open angles. These, as well as the main duct itself, are easily recognised by the whiteness of their walls, as contrasted with the darker colour of the gland tissue. The main duct receives branches from all portions of the pancreas, and towards its termination has attained a considerable size (namely, $\frac{1}{10}$th to $\frac{1}{6}$th of an inch—2·5 to 4 mm.—when fattened out, or somewhat larger than a crow quill).

The **accessory pancreatic duct** (ductus pancreaticus accessorius, Santorini) is a small and variably-developed duct (Fig. 725) which opens into the duodenum about $\frac{3}{4}$ of an inch above and somewhat in front of (*i.e.* ventral to) the pancreatic duct. From the duodenum it runs to the left and downwards, and soon divides into two or more branches, one of which joins the pancreatic duct, the others pass down and receive the ducts from the lower part of the head. It is generally supposed that the current flows from this into the main duct, and not into the duodenum, as a rule, except in early life.

Physical Characters and Structure of the Pancreas.—The pancreas is of a reddish cream colour, soft to the touch, and distinctly lobulated. The lobules are but loosely held together by their small ducts and by loose areolar tissue;

for, as already pointed out, the pancreas is devoid of a regular capsule, and possesses instead merely an adventitious coat of fine connective tissue.

The gland belongs to the class of acino-tubular glands, its alveoli or acini being elongated like those of Brunner's glands; otherwise it corresponds very closely to a serous salivary gland, the general structure of which will be found on page 958.

Variations.—The chief variations found are:—(1) A separation of the part of the head, known as the uncinate process, which then forms a *lesser pancreas*. (2) A growth of the pancreas around the duodenum, which it may practically encircle for a short part of its course. And (3) an opening of its duct into the duodenum, independently of the bile duct. An *accessory pancreas* (pancreas accessorium) is also sometimes found in the wall of the stomach or of the jejunum. Diverticula of the duodenum, already described (page 1020), ought perhaps to be mentioned in this connection.

Vessels.—The **arteries** of the pancreas are:—(1) The **superior pancreatico-duodenal**, a branch of the gastro-duodenal artery, which runs down on the front of the head (Fig. 723), sending branches outwards to the duodenum, as well as numerous twigs into the substance of the pancreas. (2) The **inferior pancreatico-duodenal**, a branch of the upper part of the superior mesenteric artery; it runs upwards and to the right across the back of the head, and sends branches to it and to the duodenum, one of which runs between the head and the duodenum. These two pancreatico-duodenal arteries anastomose around the inferior border of the head. (3) The **inferior pancreatic branch** of the superior mesenteric (or sometimes of the gastro-duodenal) artery, a considerable branch, which arises along with, or near, the last, and runs to the left along the lower border of the pancreas, often even as far as its tail. (4) **Pancreatic branches** of the **splenic artery**, are several (3 to 5) fair-sized branches which come off from the splenic as it runs behind the upper border of the gland; they enter the pancreas immediately, and traverse its substance from above downwards, some sending branches in both directions along the course of the pancreatic duct. (5) Small **pancreatic branches** also arise from the **hepatic artery** whilst it rests on the upper part of the gland, and enter it immediately. The **pancreatica magna**, which is described as accompanying the duct from left to right, does not seem to exist in the majority of cases.

The **veins** are: (1) An *anterior pancreatico-duodenal* (Fig. 723), which passes downwards and to the left, on the front of the head, and joins the superior mesenteric; (2) a *posterior pancreatico-duodenal*, which crosses the back of the head, and opens into the portal vein; (3) several small pancreatic veins which join the splenic; and (4) some from the upper part of the head and neck join the portal, which latter vein ultimately receives all the blood returned from the gland.

The **lymphatics** pass chiefly with the splenic lymphatics to the cœliac glands; some also are connected with a few glands which lie near the upper end of the superior mesenteric vessels. All the lymphatics of the organ pass ultimately to the cœliac glands.

The **nerves**, which are almost entirely non-medullated, come from the solar plexus, through the cœliac, splenic, and superior mesenteric plexuses.

Development of the Pancreas.

The pancreas is developed at a very early period in man (being visible in embryos of 8 mm.) from at least two independent hollow outgrowths, one of which takes place from the ventral aspect of the future duodenum in connection with the diverticula which form the liver; the other from the dorsal side of the tube. From this latter, which springs from the duodenum nearer to the pylorus than the ventral outgrowth, the greater part of the gland is formed, whilst the ventral diverticulum gives rise to the smaller portion. About the sixth week the two outgrowths meet, and they, as well as their ducts, fuse. At first the main duct of the gland is connected with the dorsal outgrowth; later on, the portion of this duct between the duodenum and the meeting of the two ducts lags behind in its growth, whilst the corresponding portion of the ventral duct increases rapidly in size; and finally, this latter appears to be the direct continuation of the main duct, whilst the former, and now much smaller, dorsal duct, becomes the accessory pancreatic duct. The two ducts come to open on the inner or left side of the gut, owing to the turning over of the duodenum on its right side, and the unequal growth of different portions of its wall.

The primary diverticula give off hollow lateral buds, which in their turn give off others, and this process is continued until the mass of the gland is formed. The terminal buds thus produced develop into the gland acini, whilst the others form the gland ducts.

When first formed in the embryo, the pancreas runs upwards towards the head, behind the stomach and between the two layers of the mesogastrium, so that it possesses a complete peritoneal covering. Subsequently, as a result of the changes which take place in the position of the stomach, it turns over on to its right side, and becomes adherent to the posterior abdominal wall, its head occupying the concavity of the duodenum, and its tail passing towards the spleen. The peritoneum of its posterior surface is soon lost by absorption; but it persists on its anterior aspect.

THE UROGENITAL SYSTEM.

By A. Francis Dixon.

THE URINARY ORGANS.

The **kidneys**, or glands which secrete the urine, are a pair of almost symmetrically-placed organs, situated in the posterior part of the abdominal cavity, on either side of the vertebral column and opposite its lowest movable portion. The fluid secreted by the kidneys is received into the upper expanded portions of two long tubes—the **ureters**—and is by them conducted to the **bladder**, which is placed within the pelvic cavity. From the bladder the urine is passed, during micturition, along the **urethra** to the exterior. In the male the urethra is a relatively long passage, and traverses the prostate gland and the whole length of the penis; in the female it is a short tube, and opens on the surface just above the vaginal orifice.

THE KIDNEYS.

The **kidneys**, when removed from a fresh subject, present a bean-shaped contour. They are of a dark brown-red colour, and each is surrounded by a thin glistening **capsule** (tunica fibrosa), which gives to the whole organ a uniformly smooth surface. The kidney is not a solid body, but contains a cavity called the **renal sinus,** the opening into which is termed the **hilus** (hilus renalis). The hilus is situated on the inner and anterior part of the kidney. Each kidney measures about $4\frac{1}{2}$ inches in length, 2 inches in width, and about $1\frac{1}{4}$ inch in thickness, and is placed so that its long axis is nearly vertical. The weight of the adult kidney is about $4\frac{1}{2}$ ounces. In the freshly-removed kidney the upper and lower ends are smoothly rounded, and the *upper end* (extremitas superior) is usually a little more bulky than the *lower* (extremitas inferior). The *outer border* (margo lateralis), which is opposite to the hilus, is rounded and convex, while the *inner border* (margo medialis), on which the hilus is placed, is concave from above downwards. These two borders separate the *anterior surface* (facies anterior) from the *posterior surface* (facies posterior) of the kidney.

The capsule which envelops the whole organ, is continued over the lips of the hilus into the interior of the kidney, and lines the walls of the kidney sinus. The vessels and nerves of the kidney pass through the hilus to enter or leave the sinus, within which they break up into branches. These branches, piercing the wall of the sinus, enter the solid substance of the kidney. The upper expanded portion of the ureter also leaves the sinus through the hilus.

Position of the Kidneys.—The precise level of the kidney in the abdominal cavity is subject to a considerable amount of variation, and also it is usual to find a difference in the levels of the right and left kidneys of the same individual. Most frequently the left kidney is on a higher level than the right, but in many cases the kidneys occupy the same level; or the more usual condition is reversed, and the right kidney is a little higher than the left.

If a line be drawn round the body at the level of the lowest part of the thoracic

wall, the whole, or almost the whole, of the left kidney will be found to lie above the level of the plane so determined. It is, therefore, situated in the subcostal zone of the abdominal cavity. The right kidney, however, although it lies for the most part in the subcostal zone, usually projects at its lowest part slightly below

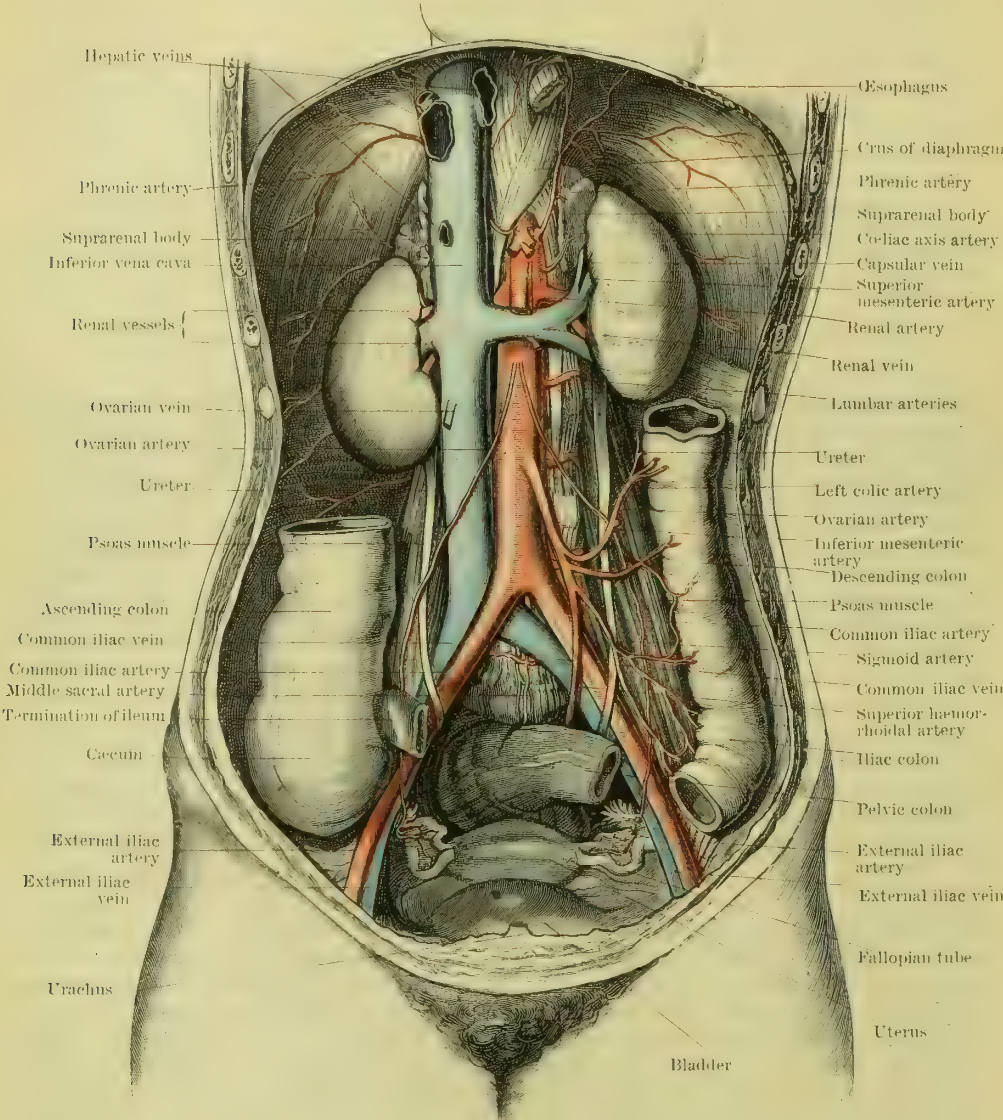


FIG. 726.—THE POSTERIOR ABDOMINAL WALL, after the removal of the stomach, liver, and the greater part of the intestines, showing the position of the kidneys, the course of the ureters, etc. (A. H. Young and A. Robinson).

the subcostal plane, and so lies to a small extent in the umbilical zone. It is stated that in the female the kidneys are placed on a somewhat lower level than in the male.

By far the greater part of each kidney lies to the inner side of a line drawn vertically upwards through the middle point of Poupart's ligament.

The posterior aspect of the kidney is closely applied against the muscles attached to the bodies of the last dorsal and upper three lumbar vertebræ, and is placed in front of the last rib and of the transverse processes of the upper three lumbar vertebræ. In some cases the eleventh rib also lies behind the upper part of the kidney; this happens more frequently on the left side of the body. The

relationship of the kidneys to the lower two ribs is very inconstant, owing partly to the great variability in size and inclination of these bones (Fig. 728).

The lower ends of the kidneys are situated from $1\frac{1}{4}$ to 2 inches above the highest part of the crest of the ilium. This distance is, of course, usually greatest on the left side.

The kidneys are placed behind the peritoneum, and project into the posterior part of the abdominal cavity. Each is surrounded by a considerable amount of

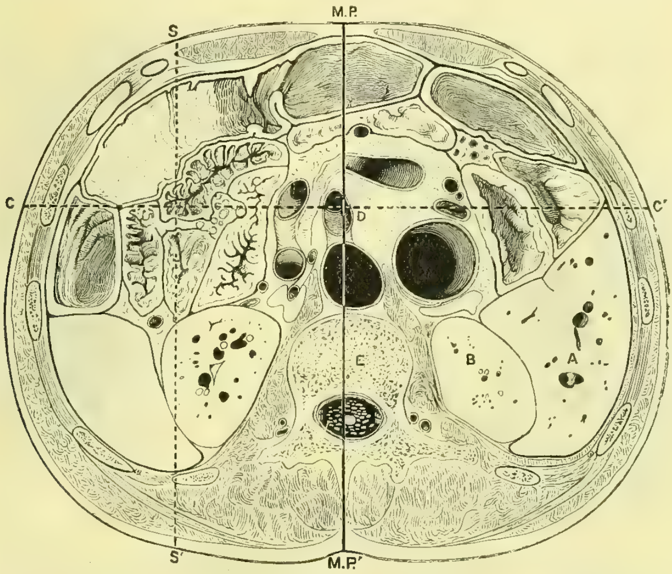


Fig. 727.—Outline of a Transverse Section through the Body at the Level of the First Lumbar Vertebra. The kidneys are seen one on each side of the vertebral column (E). The letter B is placed upon the right kidney, and its intimate relationship to the liver (A) is well seen. The left kidney at this level is closely related to the spleen (D. J. Cunningham).

loose tissue, often loaded with fat, the fatty tissue (capsula adiposa) being present in greater quantity round the margins, and only to a small extent in front of and behind the kidney. In the fat the renal vessels and nerves lie before they enter the organ, and the adipose tissue is continued, along with the vessels, through the hilus into the kidney sinus, where it fills up all the space unoccupied by the vessels and nerves.

The kidney is not held in its place by any ligaments or special folds of peritoneum, but its fixation depends, to a large extent, on the pressure and counter-pressure which is exerted upon it by neighbouring structures.

The long axis of each kidney is somewhat oblique, as the upper end of the organ approaches nearer to the middle line than the lower end. The surface of the kidney, which is applied against the muscles forming the posterior wall of the abdomen, looks, as a whole, backwards and inwards, and that which projects into the abdominal cavity looks forwards and outwards. Hence it happens that the outer border of the kidney lies on a posterior plane to the inner border. The kidney is rotated in this manner on its long axis to such a degree that the inner margin and hilus are scarcely visible from behind, and but a limited view of the outer border can be obtained in front (Figs. 729 and 730).

Posterior Relations and the Posterior Surface of the Kidney.—The muscles of the posterior abdominal wall on which the kidney rests are the psoas, the quadratus lumborum, the diaphragm, and the transversalis abdominis. The abdominal surfaces of these muscles do not lie on the same plane, but slope towards one another, and thus the bed on which the kidney rests is not flat. The posterior aspect of the kidney, when *in situ*, adapts itself to the inequalities of the surface against which it is placed, and so we find on a kidney which has been carefully fixed and hardened before it has been disturbed, areas marked off for the different planes of these muscles. When the kidney is in position, ridges or

elevations separating these areas correspond to the angles along which the different muscular planes meet. These ridges can be observed in the hardened kidney after its removal from the body, but they are usually not very sharply defined, the angles between the muscular planes being very obtuse.

A kidney hardened *in situ* (Fig. 729) presents an area near the inner part of

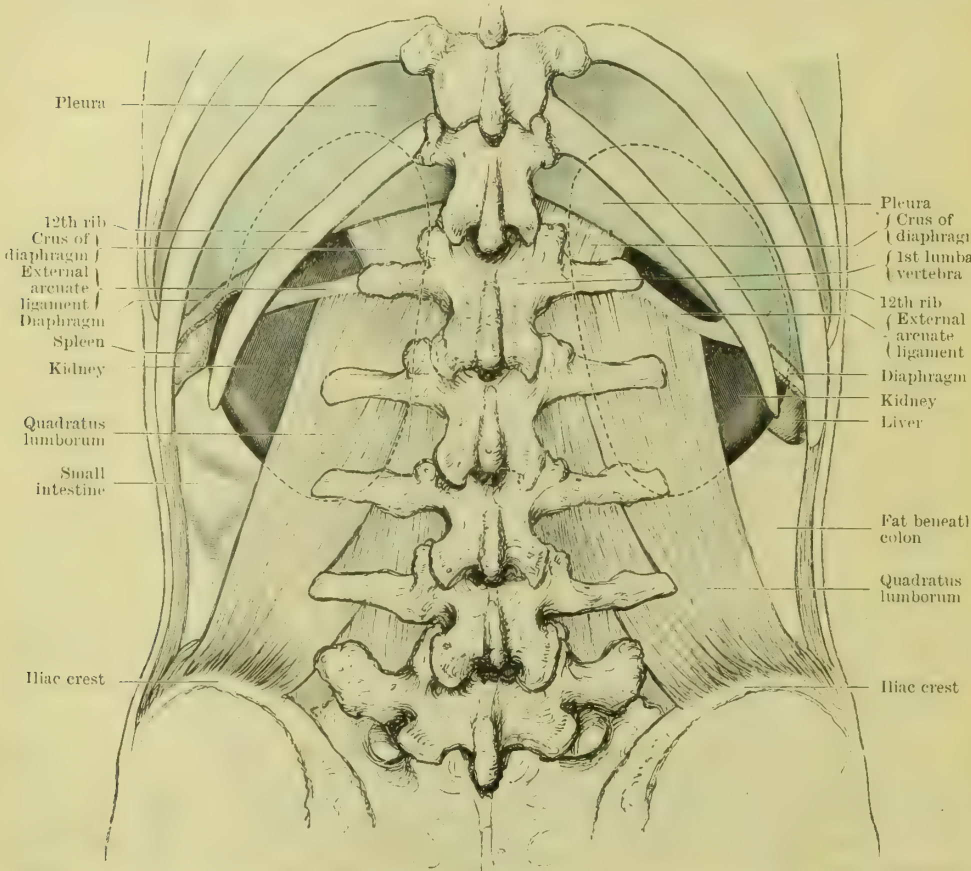


FIG. 728.—THE POSTERIOR RELATIONSHIPS OF THE KIDNEYS. The dotted lines indicate the contours of the kidneys. The drawing is made from a model prepared by Professor Cunningham.

its posterior surface adapted to the anterior aspect of the psoas muscle. This part of the posterior surface looks inwards and slightly backwards. Farther out there is a larger area which, resting against the quadratus lumborum, looks more directly backwards. These two areas are separated by a rounded ridge which fits into the angle between the muscles mentioned. Beyond the area in contact with the quadratus lumborum is the thick outer border of the kidney.

Towards the upper end of the kidney the posterior surface slopes forwards and rests upon the diaphragm. Indeed the upper part of the kidney is, as a whole, bent slightly forwards, following that part of the arch of the diaphragm on which it rests, and thus a narrow interval is left, in which the pleural cavity passes down behind the upper end of the kidney (Fig. 728). This relationship of the pleural cavity to the kidney is of importance in connexion with surgical operations performed in the lumbar region. The portions of the diaphragm to which the kidney is applied are the crus and the parts arising from the last rib and arcuate ligaments.

In addition to these surfaces or facets for the muscles with which it is in contact, the posterior aspect or outer border of the kidney often shows a groove for the last rib, another for the external arcuate ligament, and two or three depressions for the tips of the transverse processes of the upper two or three lumbar vertebræ. In some cases also faint narrow grooves are to be seen for the nerves which pass downwards and outwards between the kidney and quadratus lumborum—namely, the last dorsal nerve and the ilio-hypogastric and ilio-inguinal nerves.

It is probable that some at least of the depressions on the posterior aspect of the kidney are produced after death, and are caused by the weight of the other abdominal organs pressing the kidney backwards against the more resisting structures of the abdominal wall, at a time when the muscles behind the kidney have become flaccid.

The **outer border** in its middle and lower part is rather a surface than a border, and looks for the most part directly backwards; resting on the anterior surface of the posterior tendon of the transversalis muscle, it lies to the outer side

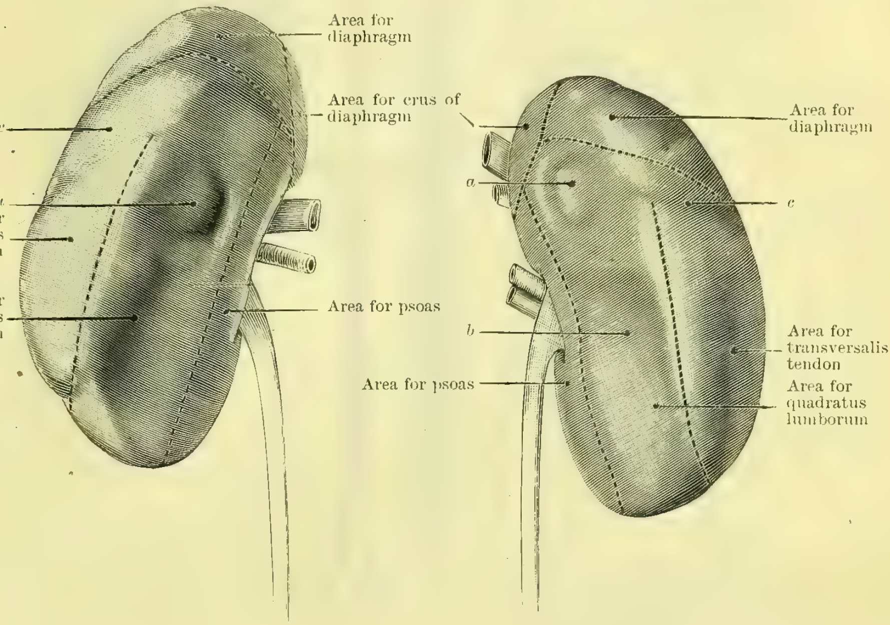


FIG. 729.—THE KIDNEYS VIEWED FROM BEHIND. Same specimen as Fig. 730. The dotted lines mark out the areas in contact with the various muscles forming the posterior abdominal wall.
a. Depression corresponding to the transverse process of the first lumbar vertebra.
b. Depression corresponding to the transverse process of the second lumbar vertebra.
c. Depression corresponding to the twelfth rib.

of the quadratus lumborum. The outer border is narrowest above, and widest just below its middle point, corresponding to the greater thickness of this part of the kidney.

In many ways it would be more satisfactory to apply the term muscular surface (facies muscularis) collectively to the areas described here as posterior surface and outer border; in like manner the term visceral surface (facies visceralis) might be suitably applied to the so-called anterior surface of the organ. The edge separating the visceral from the muscular surface is the actual outer border of the kidney.

Anterior Relations and the Anterior Surface of the Kidney.—The anterior relations of the kidneys not only differ on the two sides of the body, but also many of the structures related to the anterior surface of each kidney undergo frequent changes in position during life.

A small area on the upper part of the anterior surface of the *right kidney* is in relation to the corresponding suprarenal capsule (Fig. 730). The rest of the upper part of the anterior surface is in contact with the under surface of the liver. The suprarenal capsule is bound to the kidney by connective tissue, while the part of the kidney in relation to the liver is, like the liver itself, covered by peritoneum, and so the two organs, although closely applied, are really separated by a part of the general peritoneal cavity. In front of the lower end of the right kidney are usually found two parts of the alimentary canal—namely, the descending part of the duodenum and the hepatic flexure, or the commencement of the transverse colon. The part of the kidney related to the duodenum lies to the inner side of the area which touches the colon, but the exact amount of the kidney in contact with each of these two parts of intestine varies much in different subjects. Both

the colon and the duodenum are bound down to the kidney by the peritoneum. In addition to the structures mentioned, some portion of the ileum, or of the jejunum, is often found in contact with a small part of the right kidney.

In front of the extreme upper and inner part of the *left kidney* is the inferior portion of the left suprarenal capsule; while at a lower level the upper part of the

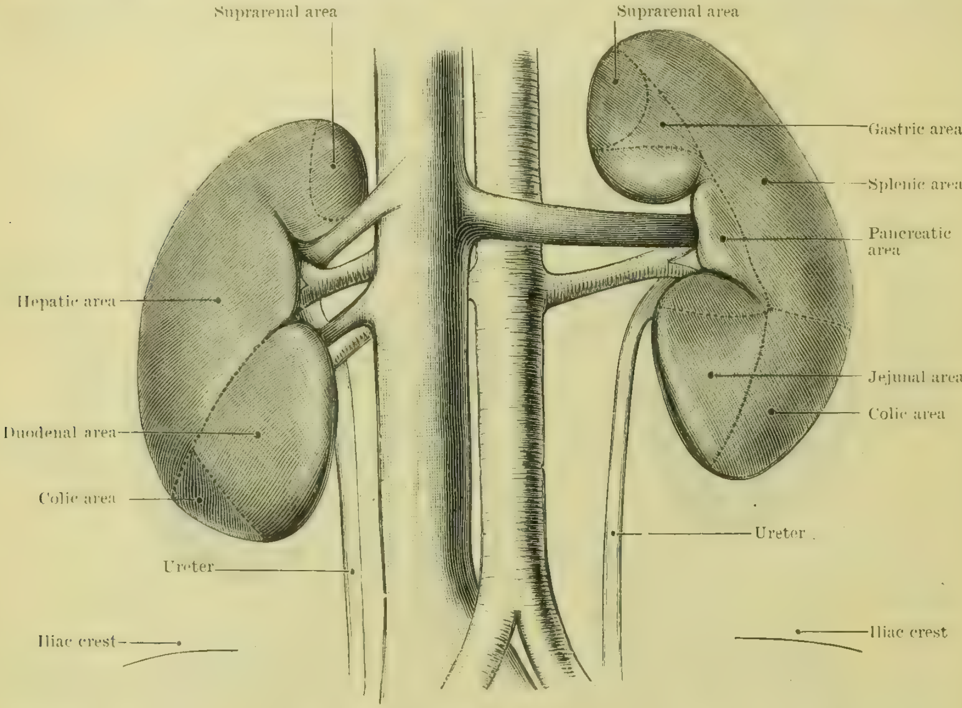


FIG. 730.—THE KIDNEYS AND GREAT VESSELS, viewed from the front. The drawing was made, before removal of the organs, from a specimen in which the viscera had been hardened *in situ*. The dotted lines mark out the areas which were in contact with the various other abdominal viscera.

left kidney is in contact with the stomach and pancreas. The suprarenal capsule and the pancreas are bound down to the kidney by connective tissue, but the stomach is separated from the part of the kidney with which it is in apposition, by the lesser sac of the peritoneum. The part of the kidney in actual contact with the stomach is usually a small, somewhat triangular area situated above the level at which the pancreas crosses the left kidney. The renal surface of the spleen is related to the anterior surface of the left kidney in its upper and outer part, the two organs being separated by a part of the general peritoneal cavity, except along the area where spleen and kidney are connected by the lieno-renal ligament. The anterior surface of the lower end of the left kidney is related, towards the inner side, to a part of the jejunum, and towards the outer side to a part of the splenic flexure of the colon.

The right and left colic arteries, or their branches, as they pass outwards to reach the colon, are often related to the anterior aspects of the corresponding kidneys. The splenic artery proceeds in front of the left kidney (Fig. 735).

The anterior surface of a kidney, which has been hardened *in situ*, is, like the posterior surface, not uniformly rounded, but marked by a series of impressions corresponding to the different structures which lie in contact with it. In the case of each kidney, the most prominent region on the anterior surface lies below the level of the middle of the kidney, and corresponds to the thickest part of the organ. From this prominence on the anterior surface a series of more or less flattened planes slope away towards the borders of the kidney. These flattened areas are the impressions formed by the viscera which lie in front of the kidney.

In the case of the *right kidney*, three impressions can usually be distinguished on the anterior surface. One occupies the whole of the upper part of the organ,

and is the **hepatic impression** (impressio hepatica); another stretches from the most prominent point to the lower end of the kidney, and is related to the colon; while the third extends along the inner margin, below the hilus, and is in contact with the second part of the duodenum (Fig. 730).

On the *left kidney*, also, three more or less marked, flattened impressions slope towards the borders of the organ from the most prominent part of the anterior surface. One of these, on the upper and outer part of the kidney, is the **splenic impression**; another, extending downwards to the lower end of the kidney, is for the colon, or for the colon and jejunum; while the third, or **impressio gastrica**, corresponds to the position of the overlying stomach. The gastric impression occupies an area of the anterior surface of the left kidney, above and in the region of the hilus. Only a small portion of this impression is directly in contact with the stomach, since the pancreas and a part of the suprarenal capsule intervene between the stomach and the kidney (Fig. 730).

It is common to find the left kidney thicker and less flattened antero-posteriorly than the right, the impressions, or facets, upon its surface being at the same time better marked. With this is probably to be associated the fact that *floating kidney* is more rarely met with on the left side than on the right.

Extremities of the Kidney.—The kidney, fixed and hardened *in situ*, is usually more pointed at its *lower* than at its *upper* end. The latter is more flattened from before backwards, and wider from side to side. This flattened part of the kidney rests upon the diaphragm, and is bent somewhat forward.

Renal Sinus (sinus renalis).—The sinus of the kidney (Fig. 731), into which the hilus opens, is a narrow space, having its long axis corresponding to that of the kidney. The thick walls of the sinus cavity are formed by the substance of the kidney, and lined by a part of the fibrous kidney capsule which enters the sinus over the lips of the hilus. The floor of the sinus is not smooth, but presents a series of small projecting conical elevations called **renal papillæ** (papillæ renales), which vary from twelve to fifteen in number. Radiating from each papilla are a number of bars or ridges of kidney substance, somewhat raised, and having depressed areas between them. The blood-vessels and nerves enter and leave the kidney by piercing the wall of the sinus where it is formed by these little depressed areas. When the vessels and nerves are removed these depressions present a cribriform appearance (areæ cribrosæ, Fig. 731). The summit of each renal papilla is pierced by a number of minute openings called **foramina papillaria**. These are the terminal apertures of the secreting tubules, of which the kidney is to a large extent composed, and the urine secreted by the kidney escapes through them into the upper part of the ureter.

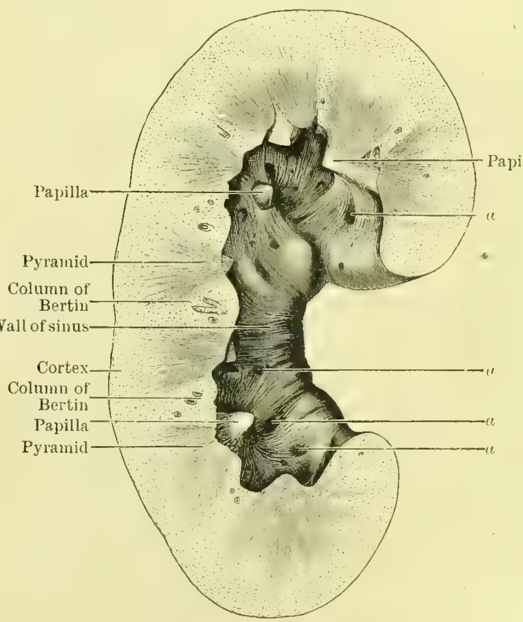


Fig. 731.—Longitudinal Section through the Kidney. The vessels and fat have been removed to give a view of the wall of the kidney sinus. The points where the vessels enter the kidney sinus are seen as little holes in the sinus wall at *a* and elsewhere.

Kidney in Section.—Sections (Fig. 731) through the kidney show it to be, for the most part, composed of a number of pyramidal masses arranged with their bases towards the surface, while their apices project into the sinus of the kidney and form the renal papillæ already described. These masses of kidney substance

are termed the **medullary pyramids** (pyramides renales), and together constitute the **medulla** (substantia medullaris) of the kidney. The bases of the pyramids do not reach the surface of the kidney, but are separated from it by a thin layer of kidney substance called **cortex**, or the **cortical part** of the kidney (substantia corticalis). The cortical substance not only covers over the bases of the pyramids, but also sends in prolongations, called **columns of Bertin** (columnæ renales), between the pyramids, towards the sinus. The medullary part of the kidney exhibits in section a striated appearance, while the cortical part is more granular and usually different in colour. The outer part of each pyramid, or the **intermediate zone** (basis pyramidis), as it is termed, appears in section to be composed of alternate dark and light streaks, while the inner or **papillary part**, which is of a lighter colour, is more uniformly and faintly striated.

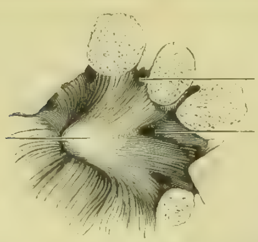


FIG. 732.—SMALL PORTION OF THE WALL OF THE KIDNEY SINUS.

In sections of the kidney the larger blood-vessels are seen, after they have entered the kidney substance, to lie between the pyramids; some of their main branches are also visible passing across the bases of the pyramids.

In the fœtus and young child, and sometimes even in the adult, the surface of the kidney is marked by a number of grooves dividing it into polygonal areas. These represent the lobes (lobi renales) of which the kidney is originally composed. Each lobe corresponds to one pyramid with its surrounding cortical substance.

An examination, with an ordinary pocket lens, of a section through the kidney shows that the lighter striæ of the intermediate zone are continued into the cortex. As they pass through the cortex towards the surface of the kidney they become less distinct, and appear as separate ray-like prolongations carried outward from the bases of the pyramids. These parts of the cortex, which appear in this way to be continuations of the medulla, are called **medullary rays** (pars radiata), and the portions of kidney cortex which intervene between them form the **labyrinth** (pars convoluta, Fig. 733).

Kidney Tubules.—The substance proper of the kidney is composed of an enormous number of minute tubules (tubuli renales), each of which has an exceedingly complicated course. The wall of a uriniferous tubule consists throughout of a basement membrane and an epithelial lining, but the diameter of the tubule and the character of the epithelium vary much in the different parts of each tube. Each tubule begins in a thin-walled spherical dilatation or **capsule** (capsula glomeruli), in which a complicated loop of capillary blood-vessels is contained. The tuft of capillaries is covered by a reflection of the delicate wall of the capsule, and is, as it were, invaginated into the capsule (Fig. 733). The capsules with their enclosed capillaries are often called **Malpighian corpuscles** (corpuscula renis), and are all placed in the labyrinth portion of the kidney cortex. The tubule leading from the capsule—**first convoluted tubule**—is much convoluted, and lies within the labyrinth. Passing from the labyrinth, the tubule enters a medullary ray, in which its course becomes less complicated, and here it receives the name of **spiral tubule**. From the medullary ray the tubule enters the intermediate zone of the pyramid, and, diminishing in diameter, it pursues a straight course towards the apex of the pyramid, forming the so-called **descending limb of Henle's loop**. Within the apical portion of the pyramid the tubule suddenly bends upon itself, forming the **loop of Henle**, and reversing its direction, it passes back again through the intermediate zone into the medullary ray as the **ascending limb of Henle's loop**. This ascending limb exhibits a slight spiral twisting. Leaving the medullary ray, the tubule once more enters the labyrinth, where its outline becomes so uneven that the name **irregular tubule** is applied to it. While still within the labyrinth, its contour having acquired a more uniform appearance, the tubule receives the name of **second convoluted tubule**; this latter finally ends in a short **junctional tubule**, which passes back into a medullary ray and joins a **collecting tube**. Each collecting tube receives numerous kidney tubules, and pursues a straight course through a medullary ray and pyramid. Finally, several collecting tubes, uniting together, open as an **excretory tube**, by one of the foramina papillaria, on the surface of a renal papilla, into a calyx of the ureter (Fig. 733).

Vessels of the Kidney.—The renal artery is very large in proportion to the size of the organ to which it conveys blood. Its terminal branches, as they approach the kidney to enter the hilus, lie between the tributaries of the renal vein in front and the ureter behind. Entering the substance of the kidney in the manner described above (page 1085), the larger branches lie in the intervals between the pyramids, and are called the **interlobar arteries** (arteriæ interlobares renis). These vessels dividing, form a series of incomplete arterial arches (arteriæ arciformes), which pass across the bases of the pyramids. From the arches two chief sets of branches come off—those of one set are continued towards the periphery and enter the labyrinth, while those of the second set pursue a recurrent course and enter the intermediate zone of the medulla. The latter vessels, called **arteriolæ rectæ**, give rise to the coarsely-striated appearance which this part of the kidney exhibits in section. Each of these vessels, entering the medulla, divides into a number of fine branches which run nearly parallel to one another, and supply the tubules in this region of the kidney. The vessels directed outwards, or **interlobular arteries** (arteriæ interlobulares), pass through the labyrinth towards the surface of the kidney. They give off a number of short branches, termed **vasa afferentia**, each of which proceeds to the dilated extremity, or capsule, of a uriniferous tubule. Here the vas afferens breaks up into a much convoluted capillary mass, called a **glomerulus**, which is contained within the invagination of the capsule. The little vein which issues from the glomerulus is termed a **vas efferens**; but instead of running directly into a larger vein, it breaks up, after the manner of an artery, into capillaries which supply the tubules of the labyrinth and medullary rays. The tubules of the intermediate zone also receive their blood-supply from the vasa efferentia of the nearer glomeruli.

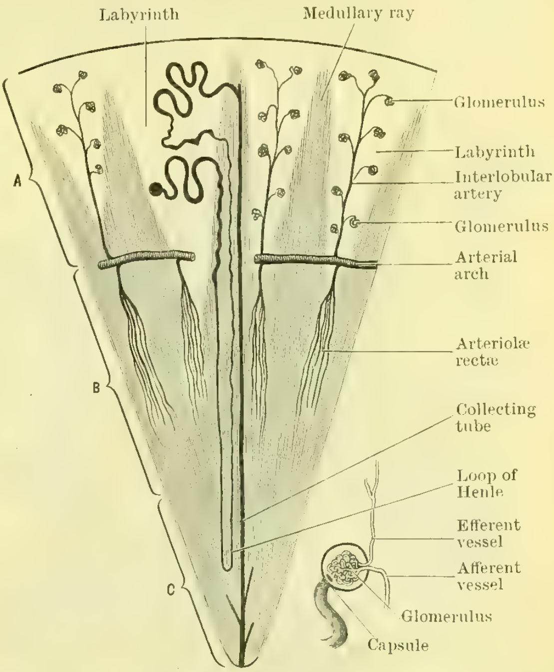


FIG. 733.—DIAGRAMMATIC REPRESENTATION OF THE STRUCTURES FORMING A KIDNEY LOBE.

In the middle part of the figure the course of one of the kidney tubules is indicated, and in the lateral parts the disposition of the larger arteries. A, Cortex; B, Intermediate zone; C, Papillary portion.

The diagram at the right-hand side of the lower part of the figure illustrates the connexions of the structures composing a Malpighian corpuscle.

Veins corresponding to the interlobular arteries and arteriolæ rectæ collect the blood from the capillaries surrounding the tubules, and unite to form a series of complete arches across the bases of the pyramids. From these venous arcades vessels arise, which, traversing the intervals between the pyramids, reach the sinus of the kidney, where they unite to form the tributaries of the renal vein.

Nerves of the Kidney.—The nerves of the kidney accompany the branches of the arteries, and are derived from the renal plexus.

Variations.—A marked difference in the size of the two kidneys is sometimes observed, a small kidney on one side of the body being usually compensated for by a large kidney on the opposite side. Cases of complete absence of one or other kidney are recorded.

Traces of the superficial lobulation of the kidney, present in the fœtus and young child, are often retained in the adult.

Horse-shoe kidney is not an infrequent abnormality. In these cases the two kidneys are united at their lower ends, across the middle line, by a connecting piece of kidney substance. The amount of fusion between the two kidneys varies much; it is sometimes very complete, while in other cases it is but slight, the connexion being chiefly composed of fibrous tissue.

In some mammalian animals, such as the bear, the ox, the porpoise, etc., the kidneys are composed of a number of completely isolated lobes, each of which corresponds to one pyramid and its surrounding cortex; while in others, such as the horse, the fusion of the lobes is more complete even than in the human kidney, and a single mass represents the united pyramids.

The Duct of the Kidney.

The duct of the kidney begins above in a thin-walled funnel-shaped expansion placed partly within and partly outside the sinus of the kidney. This portion of the duct receives the name of **pelvis** (pelvis renalis). Towards the level of the lower end of the kidney the part of the pelvis outside the sinus diminishes in calibre, and forms a tube termed the **ureter** (Fig. 734).

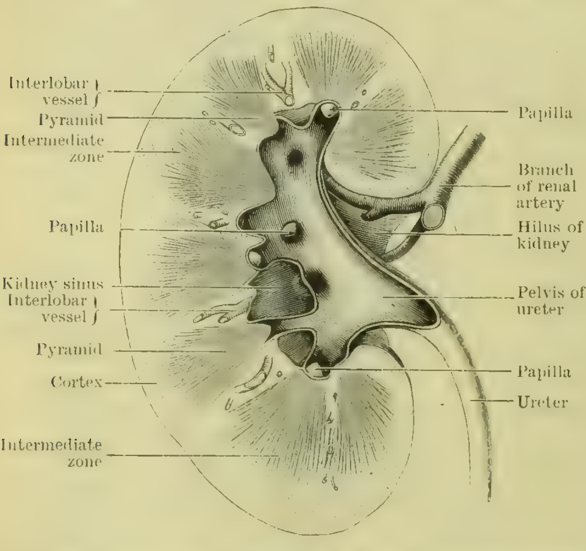


Fig. 734.—Longitudinal Section of the Kidney, opening up the Kidney Sinus.

The pelvis of the ureter and some of its calyces have been laid open as they lie within the sinus.

Pelvis of the Kidney.—Within the sinus of the kidney the pelvis lies for the most part behind the renal vessels, and is formed by the junction of two or three thin-walled tubes, each of which has a number of branches. These latter, called **infundibula** or **calyces** (calyces renales), are short, and increase in diameter as they approach the sinus wall. Their wide, somewhat funnel-like ends enclose the renal papillæ, the secretion from which they receive and conduct to the pelvis. The calyces are usually about twelve in number, one calyx sometimes surrounding two or even three papillæ. The portion of the pelvis that lies outside the kidney has in front of it, in addition to the renal vessels, on the right side the second part of the duodenum, and on the left side a part of the pancreas (Fig. 735).

Ureter.—The ureter is the vessel which carries the urine from the pelvis of the kidney to the bladder. It is a pale-coloured thick-walled duct with a small lumen. While *in situ* it has a total length of about ten inches, and lies throughout its whole course behind the peritoneum in the sub-peritoneal tissue. In its upper part the ureter lies in the abdominal cavity, and in its lower part in the pelvic cavity (Figs. 726, 735, and 736).

The normal ureter, in the flaccid condition, measures after its removal from the body eleven to fourteen inches.

The **abdominal portion** of the ureter (pars abdominalis), about five or five and a half inches in length, is directed downwards and slightly inwards, and lies upon the psoas muscle. On both sides of the body the ureter is crossed very obliquely by the spermatic, or ovarian, vessels. At its commencement the *right ureter* often lies behind the descending part of the duodenum, close to the outer side of the inferior vena cava, and as it passes downwards it is crossed, just before it enters the pelvic cavity, by the root of the mesentery. The *left ureter* is crossed by the attachment of the mesentery of the pelvic colon. On both sides the genito-crural nerve passes obliquely outwards and downwards behind the ureter (Figs. 726 and 735).

Crossing the common iliac, or sometimes the external iliac artery, the ureter enters the pelvis.

The **pelvic portion** of the ureter (pars pelvina) is about four or four and a half inches in length, and passes downwards on the side wall of the pelvis beneath the peritoneum, describing a curve which is convex backwards and outwards (Fig. 736). The most convex portion of this curve lies close to the deepest part of the great sciatic notch (Figs. 755 and 777). In its course within the pelvis the ureter lies in front of the internal iliac artery, and crosses the inner aspect of the obturator nerve and vessels and the obliterated hypogastric artery. About the level of the ischial

spine the ureter bends somewhat inwards to reach the bladder, and is crossed on its inner side by the vas deferens. A little further on it comes into relationship with the upper end of the vesicula seminalis, in front of which it lies as it pierces the bladder wall. The ureter, as it passes inwards to the bladder, is placed on

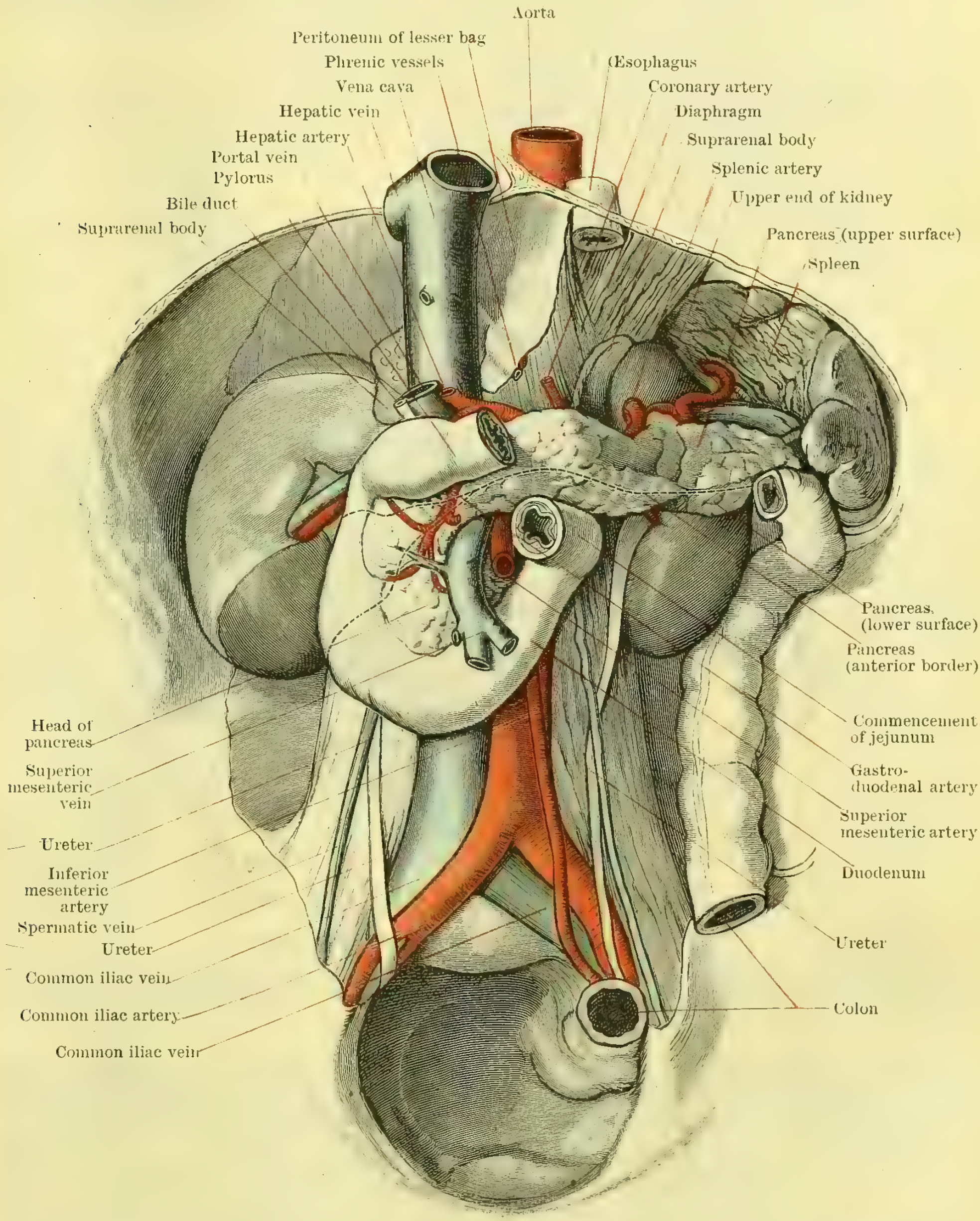


FIG. 735.—THE POSTERIOR ABDOMINAL WALL AFTER REMOVAL OF THE LIVER AND THE GREATER PART OF THE INTESTINES ; showing the position of the kidneys and the course of the ureters—(A. Birmingham)

an anterior and deeper plane than the vas deferens, and is surrounded by a dense plexus of veins, continuous with the vesical and prostatic plexuses. When the ureters reach the bladder they are a little more than two inches apart. They pierce the bladder wall very obliquely, being embedded within its muscular tissue for nearly three quarters of an inch of their length. Finally, they open into the bladder by two small slit-like apertures which are of a valvular nature, and thus prevent backward passage of fluid from the bladder. When the bladder is empty these openings are placed at about one inch apart but

when that viscus is distended they are often two inches, or more, distant from one another.

In the female, the ureter, near its termination, lies to the outer side of the cervix uteri and upper part of the vagina. It is accompanied in the lower part of its course by the uterine artery, which crosses it on its anterior aspect not far from its termination. Higher up it lies in the peritoneal fold which forms the posterior and lower boundary of the fossa ovarica (Fig. 770).

Structure of the Ureter.—The wall of the ureter is thick and of a whitish colour. Within the **outer fibrous coat** (tunica adventitia) is a **muscular coat** (tunica muscularis) of unstriated muscle fibres. This latter consists of a layer of

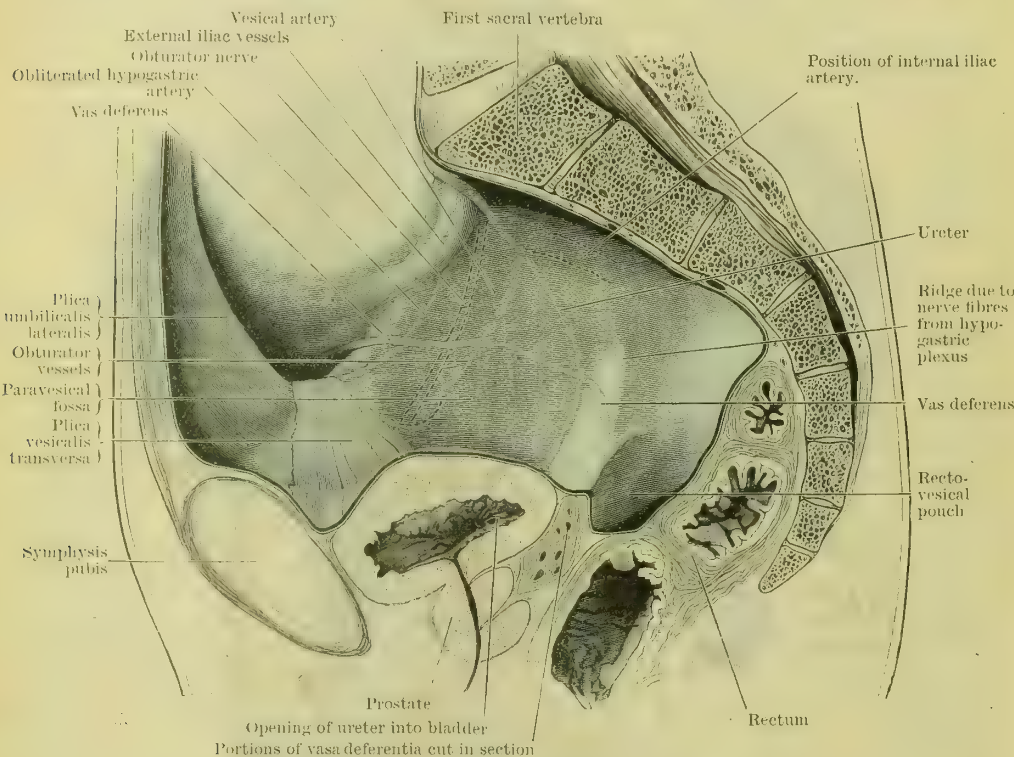


FIG. 736.—MESIAL SECTION OF AN ADULT MALE PELVIS.

The coils of the small intestine which lay within the pelvis have been lifted out in order to give a view of the side wall of the pelvic cavity. The peritoneum is coloured blue. The separation of the bladder from the prostate is indicated somewhat diagrammatically.

circularly-disposed fibres enclosed between two layers of longitudinal fibres. The inner, or **mucous coat** (tunica mucosa), which usually exhibits a number of longitudinally-disposed folds, possesses an epithelium resembling that of the bladder.

Variations.—The ureter is sometimes represented by two tubes in its upper portion. In rarer cases it is double throughout its whole length, from the pelvis of the kidney to the bladder.

THE BLADDER.

The **bladder** (vesica urinaria) is a hollow viscus into which the ureters conduct the urine secreted by the kidneys. It is placed in the anterior part of the pelvic cavity, and lies behind the symphysis pubis. The bladder is situated in front of the rectum, from which it is separated *in the male* by the seminal vesicles and the terminal portions of the vasa deferentia, and *in the female* by the vagina and uterus. Its wall is chiefly composed of muscular tissue, but the thickness of the wall and the size of the cavity depend on the amount of fluid contained within the organ. The opening into the urethra, or canal by which the urine leaves the bladder, is placed in the middle line of the under part of the bladder wall, not far

from the openings of the ureters, but on a lower level. The size and shape of the bladder, and also to a great extent its relations, vary with the amount of distension, or contraction, of the organ. When the bladder is empty, or only slightly distended, it lies within the pelvic cavity; as it becomes filled with urine it rises above the pubis, and, crossing the pelvic brim, enters the abdominal cavity. These

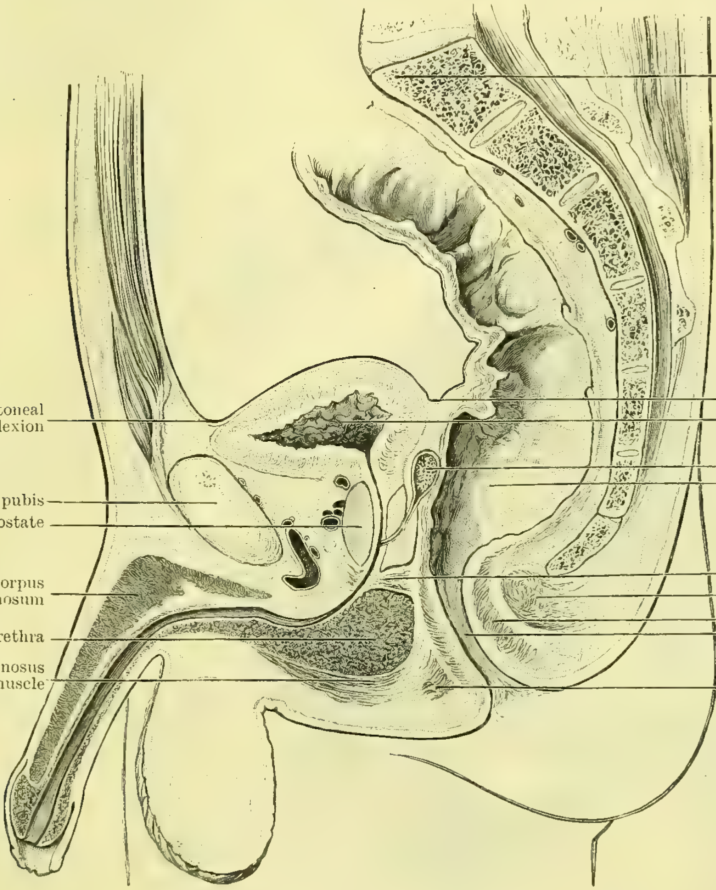


FIG. 737.—MESIAL SECTION THROUGH THE MALE PELVIS.

The bladder contains but a small amount of fluid. The separation between the bladder and prostate is shown somewhat diagrammatically. Drawn from a preparation in the Anatomical Department, Trinity College, Dublin.

changes affect chiefly the upper part of the bladder, which becomes altered in shape and size, and acquires new connexions and relations; the lower portion varies but slightly with the amount of distension of the organ (see Figs. 737 and 738). The position occupied by the bladder depends, to a certain extent, on the condition of the rectum, for when the lower part of the rectum is distended, the bladder as a whole is thrust somewhat upwards and forwards. The upper part of the bladder is covered by peritoneum, which is reflected on to it from the anterior abdominal wall in front, from the sides of the pelvis laterally, and, in the male, from the rectum behind. In the female the peritoneum passes from the anterior surface of the uterus on to the bladder. The peritoneum dips down posteriorly for a certain distance between the bladder and rectum in the male, forming the recto-vesical pouch of peritoneum; in the female a somewhat similar pouch is present between the bladder and the uterus (Fig. 744). The under part of the bladder which lies below the peritoneum is for the most part directed towards the pelvic floor. In the middle line it is supported by the symphysis pubis and the retro-pubic pad of fat; further back *in the male* it rests upon the prostate and on the lower part of the rectum, from which latter it is separated by

the vesiculæ seminales and the terminal parts of the vasa deferentia. *In the female* it rests upon the anterior wall of the vagina. Laterally the bladder is supported by the levatores ani muscles, and further from the middle line it is in contact on each side with the obturator internus; it is separated from both of these muscles by a layer of the pelvic fascia.

The opening of the urethra, or **internal urethral orifice** (orificium urethræ internum), is placed in or near the part of the bladder wall which lies lowest in the pelvic cavity. The term **neck**, or **cervix**, of the bladder is often applied to this region, as here the bladder appears as if it were suddenly constricted to form the urethra. The portion of the bladder wall behind the urethral orifice,

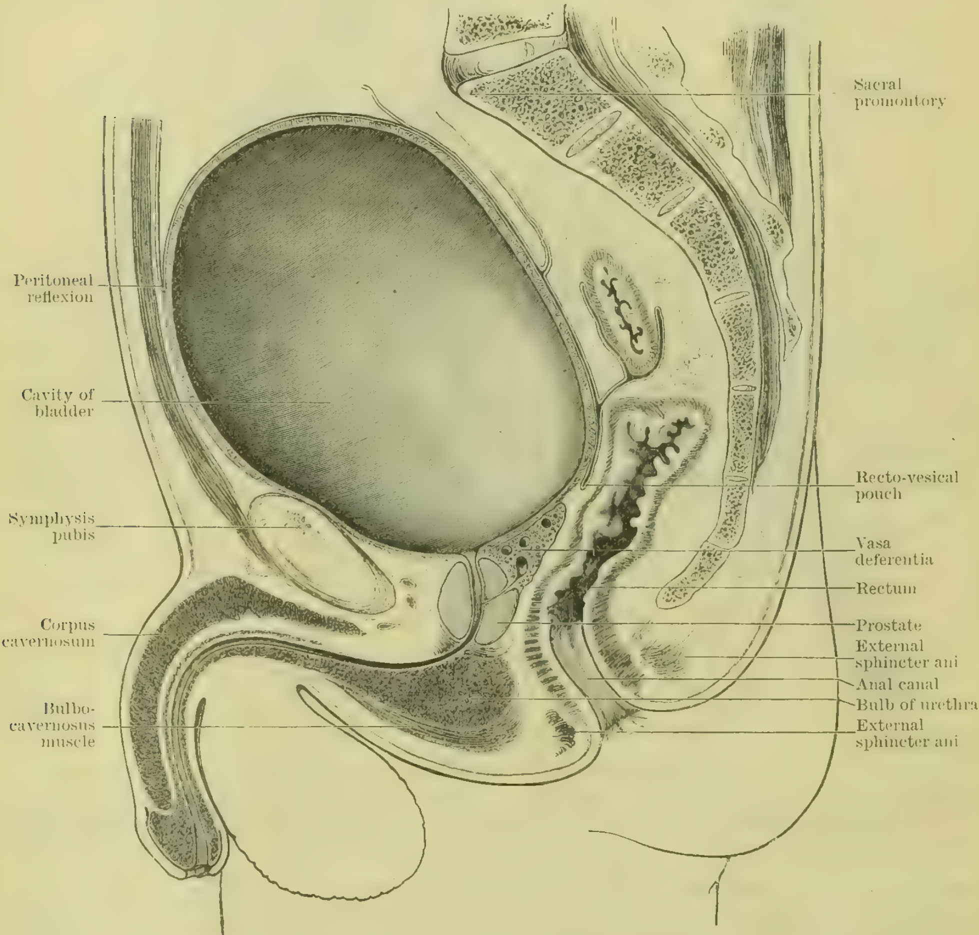


FIG. 738.—MESIAL SECTION OF THE MALE PELVIS.
The bladder has been artificially distended. From a specimen in the Anatomical Department. Trinity College, Dublin.

which is directed *in the male* towards the anterior wall of the rectum (and lies below and in front of the recto-vesical pouch), is called the **base** of the bladder (fundus vesicæ). The corresponding part of the bladder *in the female* rests against the anterior wall of the vagina. The term **apex, or summit,** of the bladder (vertex vesicæ) is applied to the portion which lies nearest to the upper border of the symphysis when the organ is empty, or but slightly filled. The apex rises high above the pubis into the abdominal cavity when the bladder is distended. Connected with the apex of the bladder is a fibrous cord (ligamentum umbilicale medium) which passes upwards, in the middle line, on the posterior aspect of the anterior abdominal wall to the umbilicus. This cord represents the **urachus,** or portion of the allantois which lies within the body of the developing embryo.

The part of the bladder which connects the apex with the base, and which is not sharply marked off from either, is called the **body**, or **corpus vesicæ**.

Position of the Urethral Orifice.—During the various changes in form and position which the bladder undergoes, the region of the urethral orifice remains almost fixed in position. When the bladder is very much distended this region merely lies at a slightly lower level in the pelvis than it does when the organ is empty; on the other hand, distension of the lower part of the rectum raises, to some extent, the level of the urethral orifice. The urethral orifice lies immediately above the prostate, behind and slightly below the level of the upper margin of the symphysis pubis, and about two to two and a half inches from it. It can be easily reached by a finger introduced into the bladder through the abdominal wall above the symphysis pubis. It is usually placed half an inch to one inch above the level of a plane passing through the lower margin of the symphysis and the lower end of the sacrum, but in some cases it is found to be somewhat lower. In the female it normally occupies a lower level than in the male. Since the position of the internal urethral orifice varies, in the manner above described, with the condition of the rectum and of the bladder itself, it follows that it lies at its lowest limit when the bladder is full and the rectum empty, and at its highest level when the bladder is empty and the rectum distended.

Under Aspect of the Bladder.—The lower part of the bladder, which is directed towards the pelvic floor, changes, as we have seen, but slightly with the varying amount of distension of the viscus. When the organ has been carefully hardened before its removal from the body, it is possible to map out on its under aspect three convex triangular areas which may be distinguished from one another by the directions in which they look. The three areas approach one another in the region of the urethral orifice, where, in the male, a portion of the under aspect of the bladder wall is structurally continuous with the upper part of the prostate. Behind the urethral orifice is a triangular district, directed downwards and backwards, and related, *in the male*, to the seminal vesicles and the terminal portions of the vasa deferentia which, together with the recto-vesical layer of the pelvic fascia, intervene between this part of the bladder and the rectum. This triangular area of the bladder wall is known as the **base**, or **postero-inferior surface** of the bladder, and *in the female* is directed against the anterior wall of the vagina. The rest of the under aspect of the bladder is formed by two **infero-lateral areas**, or surfaces, which meet in the middle line in front of the urethral orifice, and are directed for the most part downwards and outwards (see Fig. 739). Each of these areas extends backwards to join the postero-inferior surface, or base, along a rounded border which lies between the point where the ureter reaches the bladder and the urethral orifice. The infero-lateral part of the bladder wall rests against the fascia covering the levator ani and obturator internus muscles, and, nearer the middle line, upon the pubis and retro-pubic pad of fat.

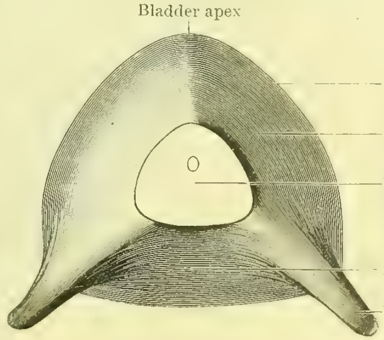


Fig. 739.—Under Aspect of the empty Male Bladder from a subject in which the viscera had been hardened *in situ*.

The prostate has been severed from the bladder, and the white area in the drawing indicates the position where the two structures were continuous.

The three rounded borders which mark off the three triangular areas on the under aspect of the bladder, just described, extend from the region of the urethral orifice to the bladder apex, and to the points where the ureters reach the bladder wall (see Fig. 739).

Shape and Relations of the Empty Bladder.—When the bladder is empty, or nearly so, it has, roughly speaking, the shape of an inverted tetrahedron, whose apex corresponds to the point where the urethra leaves the organ, while the base of the tetrahedron is formed by the superior surface of the bladder. The three

basal angles of the tetrahedron correspond to the bladder apex and to the two **lateral angles** of the bladder or points where the ureters join the organ. The three surfaces, which meet inferiorly at the urethral orifice, are only marked off from one another by rounded borders, but as long as the organ is empty, or nearly so, they are separated by distinct borders from the superior surface. These three areas have been already described as the infero-lateral surfaces and the base of the bladder. Their relations have also been indicated (Figs. 739 and 740). The **superior surface** of the empty bladder looks upwards into the pelvic cavity; it is convex when the organ is contracted, concave when relaxed. This surface is covered by peritoneum, and its outline, which is approximately triangular, is determined by lateral and posterior borders (Fig. 748). The lateral borders of the empty bladder are sharply marked, and extend from the bladder apex to the lateral angles of the bladder, or points where the ureters join the organ. The lateral borders separate the superior from the infero-lateral portions of the under aspect of the bladder wall (Fig. 741, A). The **posterior border** stretches across between the lateral angles of the bladder, and separates the superior from the basal surface of the viscus. The superior surface is related in the male to coils of intestine; in the female it is also related to the anterior surface of the uterus. The lateral border of the empty bladder lies against the pelvic fascia just above, or at the level of, the upper limit of the levator ani muscle. The vas deferens crosses the side wall of the pelvis parallel to it, but at a considerably higher level. In mesial section the cavity of the empty and relaxed bladder often presents the appearance of a Y-shaped chink, the stem of the Y being represented by the urethra as it leaves the organ, and the two limbs by the narrow intervals between the superior surface and the under parts of the bladder wall which lie in front of and behind the urethral orifice. This relaxed form is sometimes described as the diastolic condition of the empty bladder, and is found associated with a bladder wall of but little thickness, and a concave upper surface. The condition is usually the result of an escape of

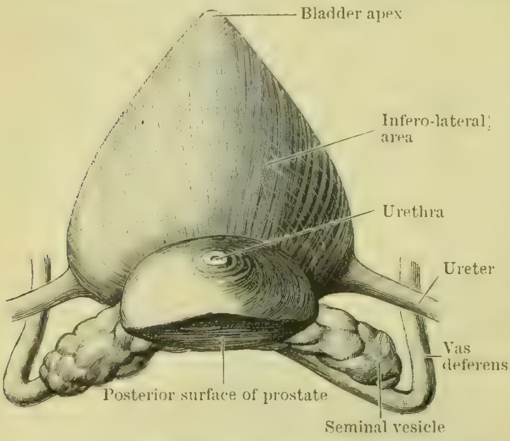


FIG. 740.—THE BLADDER, PROSTATE, AND SEMINAL VESICLES, VIEWED FROM BELOW.

Drawn from a subject in which the viscera were hardened *in situ*. Same specimen as figure 741, A. The bladder contained but a small amount of fluid.

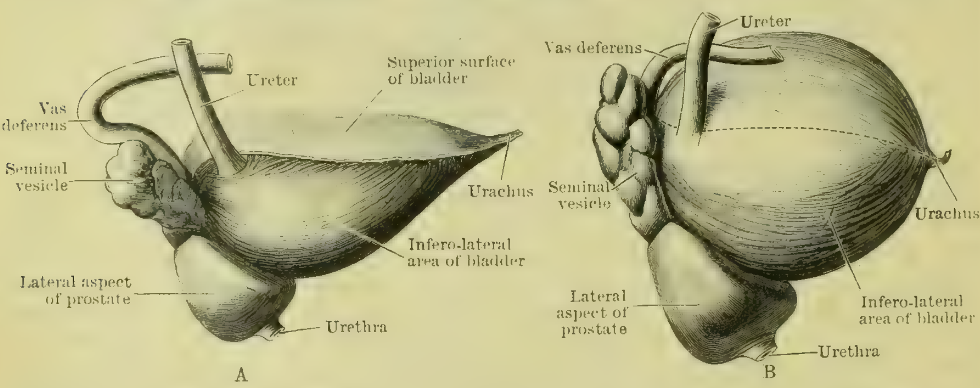


FIG. 741.—THE BLADDER, PROSTATE, AND SEMINAL VESICLE, VIEWED FROM THE OUTER SIDE.

Drawn from specimens in which the viscera were hardened before removal from the body. In A the bladder contained but a very small quantity of fluid; in B the quantity was somewhat greater. In A the peritoneum is shown covering the upper surface of the bladder, and its cut edge is seen where it is reflected along the lateral border of the organ. In B the level of the peritoneal reflexion is indicated by a dotted line.

fluid after death, when the bladder wall has lost the power of contracting. It certainly does not represent a normal condition of the organ in the living. The normal empty bladder is strongly contracted, and its wall is thick and firm. A distinctly Y-shaped appearance is not presented by its cavity in mesial section, but the interior of the organ is seen as a simple narrow interval continuous with the canal of the urethra.

Distended Bladder.—As the bladder fills with fluid the superior wall is raised upwards from the intero-lateral and basal walls, and, at the same time, the borders separating the superior from the other surfaces of the bladder become at first more rounded and then obliterated. The lateral borders of the bladder, becoming in this manner opened out, give rise to so-called **lateral surfaces** in the

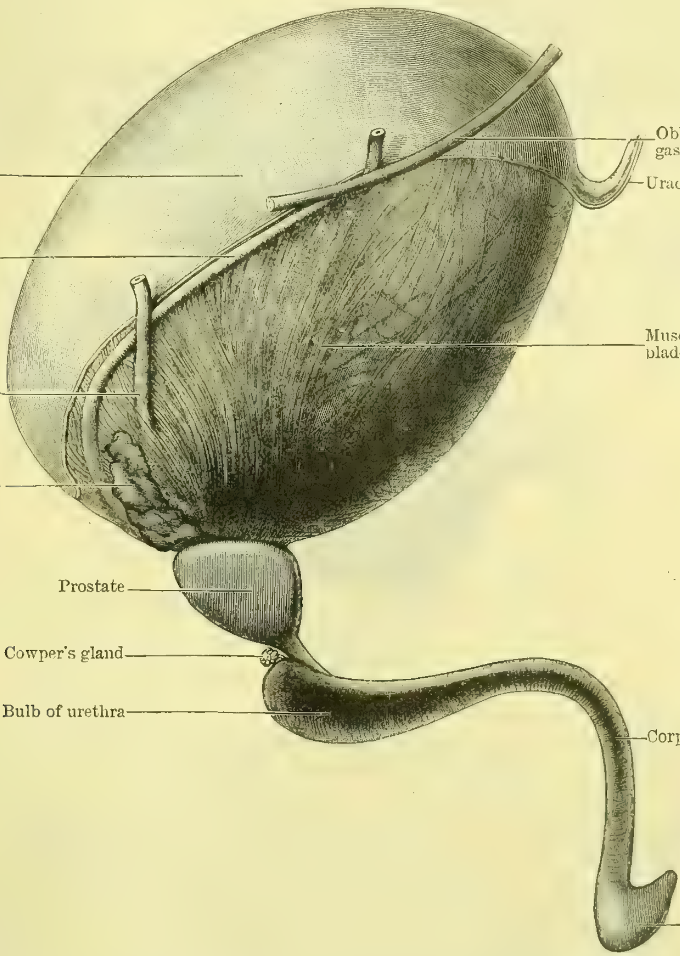


Fig. 742.—The Bladder, and the Structures traversed by the Urethra in the Male, viewed from the outer side. The bladder has been artificially distended.

distended organ. These surfaces, however, are not sharply marked off from the infero-lateral surfaces, and are directly continuous with the superior surface. During distension, also, the angles present in the empty condition of the organ become rounded as the entire bladder wall becomes more uniformly convex. In mesial section the cavity of the bladder becomes circular or oval in outline, and the highest part of the bladder, when much distended, lies at some distance above the pelvic brim. The highest part of the distended bladder does not correspond to the attachment of the urachus at the apex, but lies behind this point (Fig. 742). As the superior wall of the bladder is raised up it carries with it the peritoneum, and thus the reflexion of that membrane, from the anterior abdominal wall on to the apex of the bladder comes to lie one and a half inches, or even higher, above the upper margin

of the symphysis pubis (Fig. 738). Thus it is possible, when the organ is distended, to puncture, or open into the bladder, through the anterior abdominal wall above the symphysis pubis, without at the same time opening into the peritoneal cavity. In the same manner the line of reflexion of the peritoneum, from the side wall of the pelvis on to the lateral aspect of the bladder, is also raised higher, and may come to correspond, in part, to the level of the vas deferens, or to that of the obliterated hypogastric artery (Figs. 742 and 743). On the other hand, the level of the reflexion of the peritoneum from the rectum towards the basal aspect of the bladder does not appear to vary much with the distension or contraction of the organ (compare Figs. 737 and 738), and thus the fossa between the bladder and rectum becomes relatively very deep when the bladder is full. The bladder in normal distension may contain as much as one pint, but in most cases the bladder is emptied when its contents reach from six to ten ounces. Under abnormal or pathological conditions the bladder capacity may be much increased.

Varying Relationships, according to the degree of Distension of the Bladder.—When the bladder is distended the obliterated hypogastric artery may cross forwards against its side; when it is empty the obliterated vessel lies, at its nearest

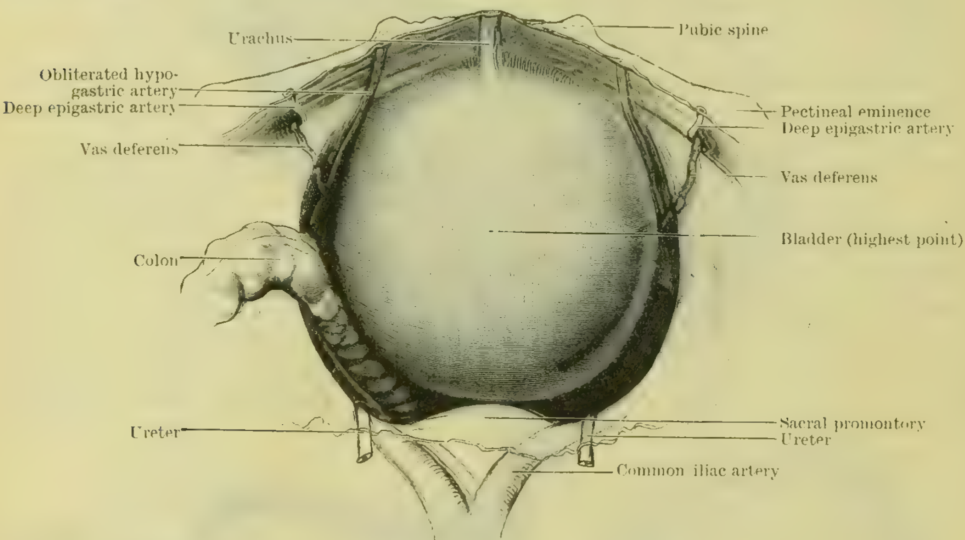


FIG. 743.—VIEW LOOKING INTO THE PELVIS FROM ABOVE AND SOMEWHAT BEHIND. The bladder has been artificially distended.

point, often as much as one and a quarter inches above the lateral border of the organ (Figs. 736 and 742). The vas deferens, during a part of its course, is in contact with the side wall of the distended bladder, but when the organ is empty it lies above and parallel to the lateral border, only coming into relationship with the basal surface of the bladder after it has crossed the ureter. The side wall of the distended bladder is closely related to the obturator vessels and nerves.

Bladder in the Female.—In the female the bladder is related behind to the uterus and upper part of the vagina. The anterior surface of the uterus in its upper part is separated from the upper surface of the bladder by the shallow utero-vesical pouch of peritoneum, but the two organs are nevertheless normally in apposition. So close is this relationship that the upper surface of the bladder very often shows a slight concavity, due to contact with the convex anterior wall of the uterus. The lower part of the uterus and upper part of the vagina are not separated by peritoneum from the basal surface of the bladder, but are in actual apposition with it (Fig. 744). Thus, below the level of the utero-vesical pouch, the female bladder is related in much the same manner to the uterus and anterior wall of the vagina as the male bladder is related to the vesiculæ seminales and vasa deferentia. The apex of the bladder, where the urachus is attached, often lies on a lower level than in the male, so that the organ, even when distended, rises less

freely into the abdomen. The bladder as a whole is placed deeper in the pelvis

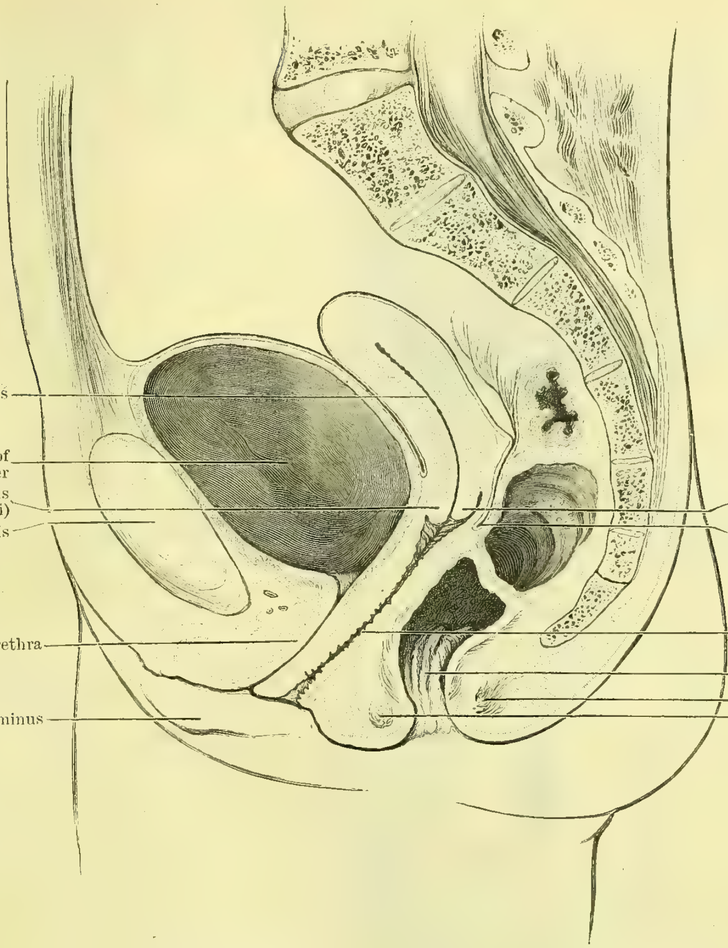


Fig. 744.—Mesial Section of the Pelvis in an Adult Female.

The cavity of the uterus is indicated diagrammatically. From a specimen in the Anatomical Department, Trinity College, Dublin.

than in the male, and the internal urethral orifice lies just above or just below a line drawn from the lower margin of the symphysis to the lower end of the sacrum (p. 1093). The lower level of the internal urethral orifice is probably correlated with the absence of the prostate in the female. The female bladder has normally a smaller capacity than that of the male.

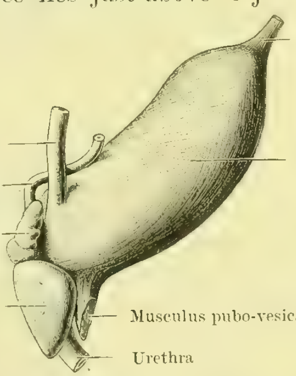


Fig. 745.—The Bladder of a newly-born Male Child, viewed from the outer side.

The drawing is from a specimen which had been hardened *in situ*.

Bladder in the Newly-born Infant and in the Child.—At birth the empty bladder is spindle or torpedo-shaped, and its long axis, which extends from the point of attachment of the urachus to the internal urethral orifice, is directed downwards and backwards (Fig. 745). The lateral and posterior borders seen in the adult organ cannot be recognised at birth. In the fœtus and young child the bladder occupies relatively a much higher level than it does in the adult, and, even when

empty, it extends upwards into the abdominal cavity. Its anterior aspect is in contact with the posterior surface of the anterior abdominal wall. At birth the peritoneum forming the recto-vesical pouch covers the whole of the posterior surface of the bladder, and reaches as low as the upper limit of the prostate. The internal urethral orifice is placed at a high level, and sinks gradually after birth (Fig. 746, A). In the newly-born child this opening lies on a level with the upper margin of the symphysis pubis, and the openings of the ureters lie almost on a level with the plane of the pelvic brim. The obliterated hypogastric arteries are more intimately related to the bladder in the fœtus and child than in the adult, and lie close against its sides as they pass upwards towards the umbilicus (Fig. 757).

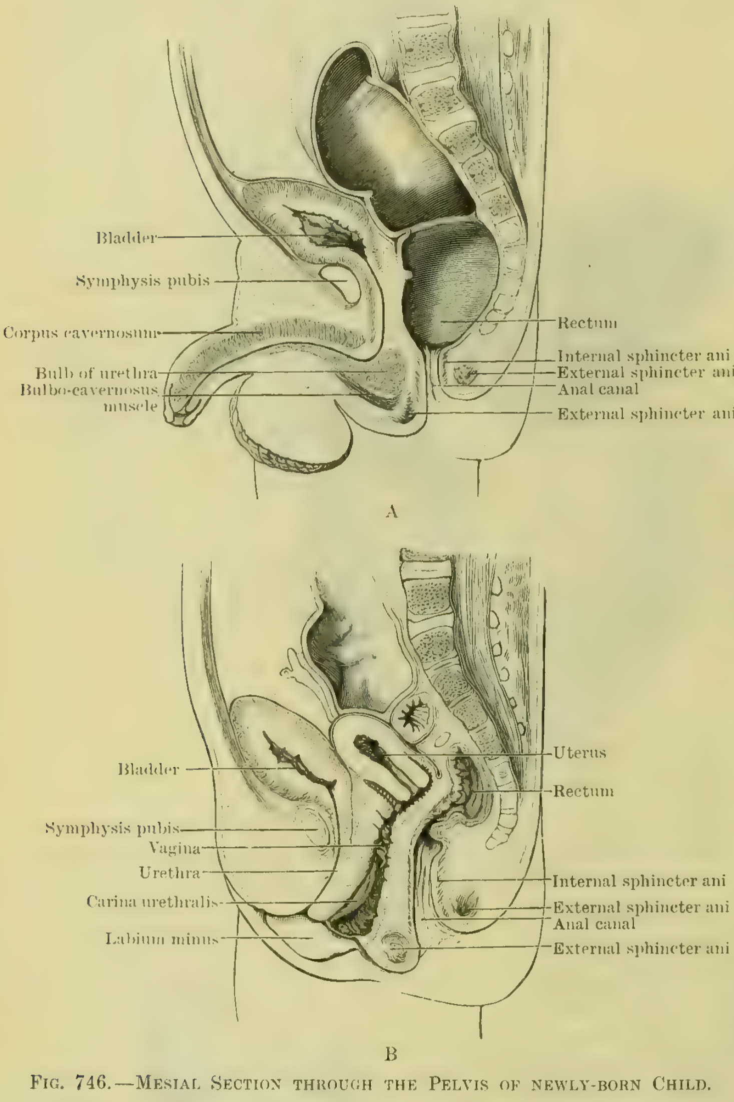


FIG. 746.—MESIAL SECTION THROUGH THE PELVIS OF NEWLY-BORN CHILD. A, Male, and B, Female. From preparations in the Anatomical Department, Trinity College, Dublin.

Interior of the Bladder.—The mucous membrane lining the bladder is but loosely connected to the muscular coat, and when the bladder is contracted the mucous lining is thrown into a number of prominent wrinkles or folds (Fig. 747). At one place only the mucous membrane is firmly connected to the subjacent muscular coat, and the inner surface of this part of the bladder wall is smooth and free from wrinkles. This smooth area, called the **trigonum vesicæ**, corresponds to a triangular surface behind the urethral orifice and to the part of the bladder wall which immediately surrounds the opening. The base of the triangle is formed by a line drawn between the openings of the ureters into the bladder, and the apex lies at the beginning of the urethra. Just behind the urethral opening the bladder wall bulges slightly into the cavity, owing to the presence beneath it of the middle lobe of the prostate. When well marked, as it often is in old people, this elevation is termed the **uvula vesicæ**. Stretching across between the openings of the ureters there is usually to be seen a smooth curved ridge, which is due to the presence of a bundle of transversely-disposed muscle fibres within this part of the bladder wall, beneath the mucous membrane. The lateral portions of this ridge are called the

plicæ uretericæ, and are produced by the terminal parts of the ureters as they traverse the bladder wall (Fig. 747). Round the urethral orifice are a number of minute radially-disposed folds which, disappearing into the urethra, become continuous with the longitudinal folds of the mucous membrane of the first part of that canal. The ureters pierce the bladder wall very obliquely, and so the minute opening (orificium ureteris) of each has an elliptical outline. In the empty bladder the urethral orifice and the openings of the two ureters lie at the angles of an approximately equilateral triangle, whose sides are about one inch in length. When the bladder is distended, the distance between the openings may be increased to one and a half inches or more.

FIG. 747.—VIEW OF THE INTERIOR OF THE BLADDER IN THE REGION OF THE URETHRAL ORIFICE.

Peritoneal Relations and Connexions of the Bladder.—We have already seen that the superior surface of the empty bladder is covered by peritoneum, which leaves it along the lateral border on each side to reach the pelvic wall about the level of the white line (arcus tendineus) of the pelvic fascia. To this peritoneal reflexion the term **lateral false** (or peritoneal) **ligament** is usually applied. The lateral ligaments of opposite sides are continuous in front at the bladder apex, in which position the peritoneum is conducted over the fibrous cord of the urachus to reach the anterior abdominal wall, forming the so-called **anterior false** (or peritoneal) **ligament**. When the bladder is empty the level of this anterior reflexion lies just behind or just below the upper margin of the symphysis pubis. When the bladder becomes filled the level of the peritoneal reflexion forming the anterior false ligament is raised upwards, and may reach a point two inches or more above the upper margin of the symphysis pubis. Similarly, the line along which the lateral peritoneal ligament reaches the pelvic wall is also carried upwards in distension of the bladder, and may reach the level of the vas deferens or of the obliterated hypogastric artery.

When the bladder is empty the peritoneum is carried downwards upon the side wall of the pelvis as low as the lateral border of the organ, and lines a groove or depression in this position which receives the name of **paravesical fossa**. As the bladder fills the peritoneum is raised off this fossa, and certain structures, such as the obturator vessels and nerves and the vas deferens, which lie in the floor of the fossa, come into direct relationship with the side wall of the distended bladder.

Posteriorly the peritoneum leaves the upper surface of the empty bladder at its posterior border, and is carried backwards, forming a kind of horizontal shelf or fold for a distance of about half-an-inch, giving at the same time a partial covering to the vasa deferentia and upper ends of the seminal vesicles. The peritoneum then suddenly dips downwards to reach the bottom of the recto-vesical pouch, where it is reflected on to the anterior surface of the rectum (Fig. 749). As a rule, no part of the basal surface of the contracted and empty bladder receives a covering from the peritoneum, since the seminal vesicles and terminal portions of the vasa deferentia intervene as they lie in the anterior wall of the recto-vesical pouch. When the bladder is distended the posterior border, separating the upper and basal surfaces, is rounded out, and the peritoneum forming the horizontal shelf, just described, is taken up (compare Figs. 736 and 738). It is to be specially noted that the level of the peritoneal reflexion, forming the bottom of the recto-vesical pouch, does not alter to any considerable extent in distension of the bladder (Figs. 737 and 738).

An examination of mesial sections of the pelvis shows the great danger run by the ampullæ of the vasa deferentia in the operation of puncturing the bladder through the anterior wall of the rectum, while avoiding at the same time injury to the peritoneum.

The term **posterior false** (or peritoneal) **ligaments** is often applied to the somewhat variable crescentic folds of peritoneum which bound the entrance to the recto-vesical pouch on each side, and which often become continuous across the middle line, behind the posterior border of the bladder and the vasa deferentia. They represent the folds of Douglas in the female, and are to be looked upon as con-

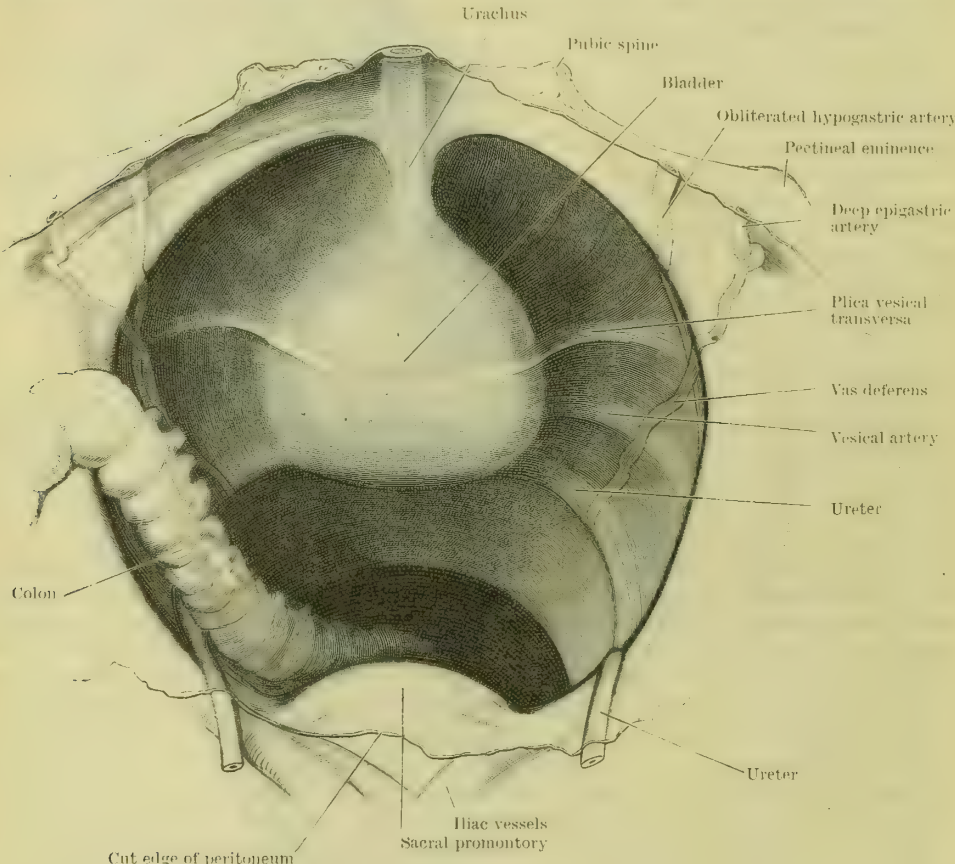


FIG. 748.—VIEW LOOKING INTO THE MALE PELVIS FROM ABOVE AND SOMEWHAT BEHIND.

From a specimen in which the bladder was firmly contracted and contained but a small amount of fluid. The paravesical fossa is seen on each side of the bladder. The deep peritoneal pouch in front of the rectum is bounded by marked crescentic folds, which meet together some distance behind the posterior border of the bladder.

nexions of the vasa deferentia rather than of the bladder. The folds are seen in Figs. 748 and 749.

In the female the peritoneum is reflected from the upper surface of the bladder posteriorly on to the anterior aspect of the uterus.

The peritoneum covering the upper surface of the empty or partly distended bladder often exhibits a transversely-disposed fold or wrinkle, to which the term **plica vesicalis transversa** has been applied. This fold, when well developed, can be traced on to the side wall of the pelvis, where it traverses the fossa paravesicalis, and in some cases it is found to cross the pelvic brim and to be directed towards the internal abdominal ring (Figs. 748 and 749).

Fixation of the Bladder.—When the fibrous cord of the **urachus** (ligamentum umbilicale medium), which binds the bladder apex to the anterior abdominal wall and the peritoneal folds, already described as the false ligaments, are severed, the bladder is easily moved about, except in its lower and basal parts. The lower fixed part is chiefly held in place by processes of the pelvic fascia, continuous with those forming the capsule of the prostate. The fascial connexions constitute the true

ligaments of the bladder, and are described as **pubo-prostatic** or **anterior ligaments**, reaching the bladder from the pubis in front, and **lateral ligaments**, reaching the bladder from the fascial lining of the side wall of the pelvis.

In addition to the urachus and the peritoneal and true ligaments already mentioned, the bladder is supported and fixed in position, in the region of its

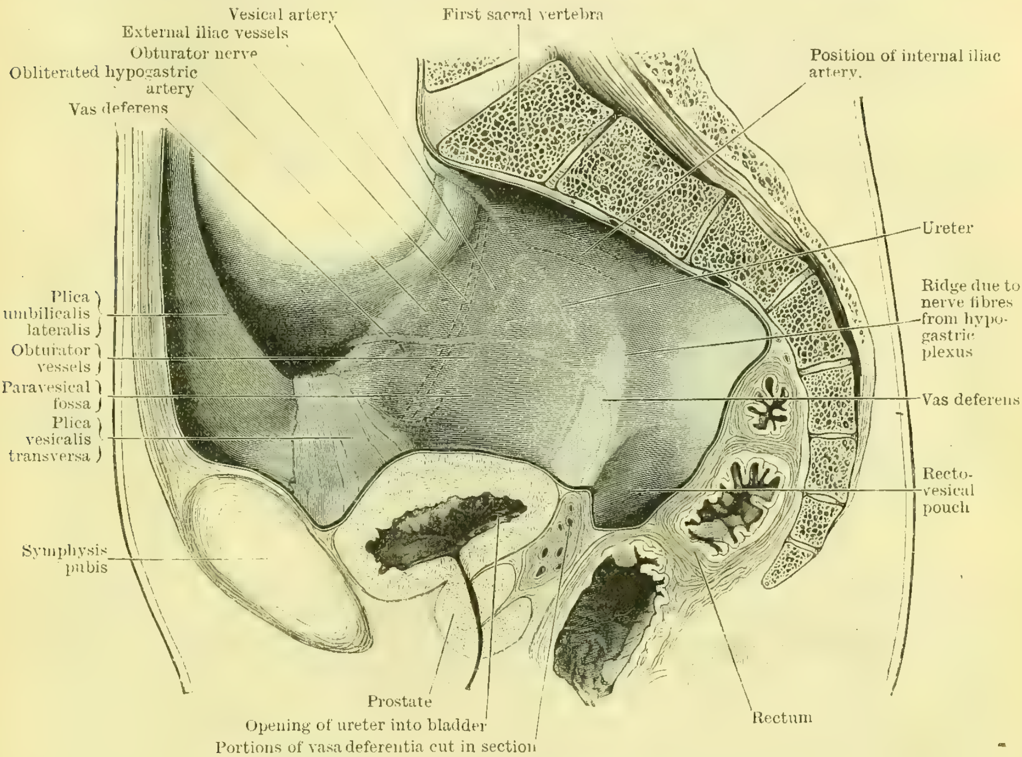


Fig. 749.—Mesial Section of the Pelvis in an Adult Male.

The coils of small intestine which lay within the pelvis have been lifted out in order to give a view of the side wall of the pelvic cavity. The peritoneum is coloured blue. The separation of the prostate from the bladder is indicated somewhat diagrammatically.

basal surface, by the dense fibrous and unstriped muscular tissue which surrounds the seminal vesicles, the terminal portions of the vasa deferentia, and the ureters.

Laterally the strands of connective tissue and the bundles of muscle fibres forming this support pass backwards to gain attachment to the fascia in connexion with the rectum, and the front of the sacrum. Muscle fibres connected with the bladder wall are also found within the pubo-prostatic ligaments, through which they are attached to the pubis.

In the female the basal part of the bladder wall is supported and held in place by its connexion with the anterior wall of the vagina. The region of the urethral orifice is the most firmly fixed part of the bladder wall in both sexes.

Structure of the Bladder.—The wall of the bladder from without inwards is composed of a serous, a muscular, a submucous, and a mucous coat. The **serous coat** (tunica serosa), formed by peritoneum, is incomplete, and covers only the upper and posterior parts of the distended bladder (Fig. 742).

The **muscular coat** (tunica muscularis) is composed of three imperfectly separated strata, called external, middle, and internal. The **external stratum** (stratum externum), in the middle line of the organ, is made up of longitudinally-directed bundles of muscle fibres. These have an attachment in front to the lower part of the back of the symphysis pubis, where they constitute the **musculus pubo-vesicalis.** Further from the middle line (on the sides of the bladder) the fibres composing the external stratum run more obliquely, and frequently cross each other. The **middle stratum** (stratum medium) is composed of

muscle fibres which, near the urethral orifice, run circularly in a horizontal direction. These form a distinct layer over the base of the bladder and in the region of the urethral orifice, but elsewhere the bundles of fibres are separated from one another by considerable intervals, and are directed obliquely. The circular fibres in the region of the urethral orifice are sometimes described as forming a **sphincter vesicæ.** The **inner stratum** (stratum internum) is a thin layer of fibres directed for the most part longitudinally.

The **submucous coat** (tela submucosa) is composed of areolar tissue, but contains numerous fine elastic fibres.

The **mucous coat** (tunica mucosa) is loosely attached, through the submucous layer, to the subjacent muscular coat, except over the trigonum vesicæ. Over the trigonum it is always smooth and flat; elsewhere it is thrown into folds when the organ is empty. The mucous membrane of the bladder is continuous with that of the ureters and urethra. The epithelium covering it varies much in appearance in different conditions of the organ, and is of the variety known as transitional stratified epithelium.

Vessels and Nerves of the Bladder.—The bladder receives its blood supply on each side from the **superior** and **inferior vesical arteries.** The superior vesical artery arises from the pervious part of the hypogastric artery, and the inferior vesical from the internal iliac. The largest veins are found just above the prostate, and in the region where the ureter reaches the bladder. They form a dense plexus which pours its blood into tributaries of the internal iliac vein, and communicates below with the prostatic plexus. The **lymphatics** from the bladder join the iliac group of glands.

The nerve supply of the bladder is derived on each side from the **vesical plexus,** the fibres of which come from two sources, namely (1) from the **upper lumbar nerves** through the hypogastric plexus, and (2) from the **third** and **fourth sacral nerves.** The fibres from the latter sources join the vesical plexus directly.

THE URETHRA.

The **urethra** is the channel which serves to convey the urine from the bladder to the exterior. In the *male* it consists of two portions, a proximal part, less than one inch in length, extending from the bladder to the points where the ducts of the reproductive glands join the canal, and a much longer distal portion which serves as a common passage for the secretion of the kidneys and for the generative products. An account of the male urethra follows the description of the male reproductive glands and passages (see p. 1119). In the *female* the urethra is more simple in its arrangement, and represents only the proximal part of the male urethra. It is a short passage leading from the bladder to the external urethral orifice—an aperture placed within the urogenital cleft immediately above and in front of the opening of the vagina.

Female Urethra.—The female urethra (urethra muliebris) is a canal of one to one and a half inches in length, which follows a slightly curved direction downwards and forwards, below and behind the lower border of the symphysis pubis. As it leaves the pelvis the urethra pierces the triangular ligament, and the part of the passage which lies between the deep and superficial layers of this ligament is surrounded by the fibres of the compressor urethræ muscle. Except during the passage of fluid the canal is closed by the apposition of its anterior and posterior walls. The **external orifice** (orificium urethræ externum) is placed between the labia minora, immediately in front of the opening of the vagina, and lies about one inch below and behind the clitoris (Fig. 778). The opening is slit-like, and is bounded by slightly marked lateral lips. The posterior wall of the urethra, except in its upper part, is intimately connected with the anterior wall of the vagina. The mucous lining of the canal is raised into a number of slightly marked longitudinal folds, one of which, more distinct than the others, and placed upon the posterior wall of the passage, receives the name of **crista urethralis.**

Structure.—The muscular coat of the urethra (tunica muscularis) is continuous above with that of the bladder, and composed of layers of circularly and longitudinally disposed muscle fibres. Within the muscular coat the wall of the urethra is very vascular, and the canal itself is lined by a pale mucous membrane which is thrown into longitudinally-directed folds, one of which is the crista urethralis mentioned above. The epithelium of the canal, in its upper part, is of the transitional variety, like that of the bladder; in its lower part, however, it becomes scaly. Numerous mucous glands (glandulæ urethrales)

open into the urethral canal. One group of these mucous glands possesses a minute common duct (ductus paraurethralis), which opens into the urogenital cleft by the side of the urethral orifice. The vascular layer which lies between the muscular coat and the

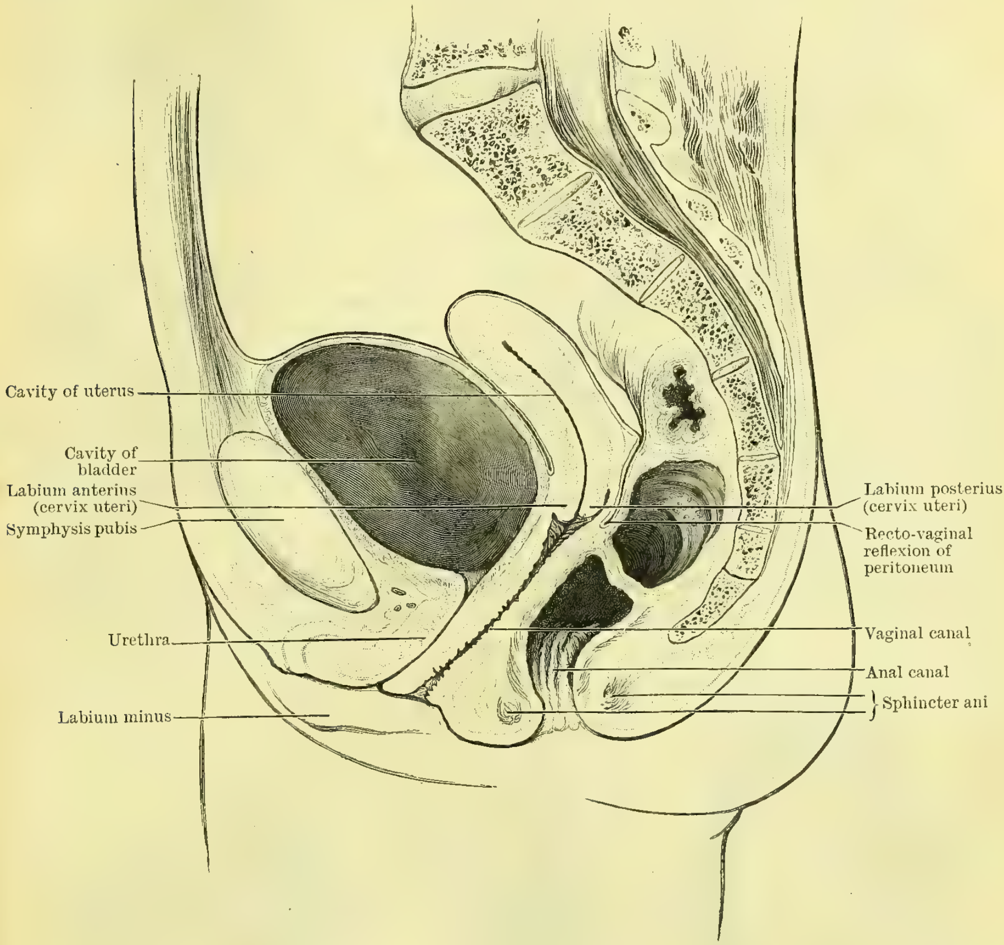


FIG. 750.—MESIAL SECTION OF THE FEMALE PELVIS.

The cavity of the uterus is shown somewhat diagrammatically. From a specimen in the Anatomical Department, Trinity College, Dublin.

mucous membrane contains elastic fibres, and in appearance resembles erectile tissue. Striped muscle fibres are also found in connexion with the female urethra, and are especially plentiful in the lower part of the anterior wall of the passage.

THE MALE REPRODUCTIVE ORGANS.

We have here to describe (1) the testes or essential reproductive glands of the male, together with their (2) coverings and (3) ducts, (4) the prostate, (5) Cowper's glands, (6) the external genital organs, and (7) the male urethra.

The reproductive glands of the male, or **testes**, are a pair of nearly symmetrical oval-shaped bodies situated in the scrotum. The duct of each gland, at first much twisted and intertwined, forms a structure known as the **epididymis**, which is applied against the posterior and outer part of the testis. From the epididymis the excretory duct or **vas deferens** passes upwards towards the lower part of the anterior abdominal wall, which it pierces very obliquely, to enter the abdominal cavity. Here each vas deferens is covered by peritoneum, and, crossing the pelvic brim, enters the pelvis. The vas now runs on the side wall of the

pelvis towards the base of the bladder, where it comes into relation with a branched tubular structure termed the **vesicula seminalis.** Joined by the duct of the vesicula seminalis, the vas deferens forms a short canal called the **common ejaculatory duct**, which terminates by opening into the prostatic part of the **urethra.** The **prostate**, a partly glandular, partly muscular structure, surrounding the first part of the urethra, and also a pair of small glandular bodies called **Cowper's glands**, are accessory organs connected with the male reproductive system. The ducts of Cowper's glands and those of the prostate, like the common ejaculatory ducts, open into the urethra, which thus serves not only as a passage for urine, but also for the generative products. The external genitals are the **penis** and **scrotum.**

THE TESTIS.

The male reproductive glands or **testes** are a pair of somewhat oval, slightly flattened bodies of a whitish colour, measuring about an inch and a half in length, one inch from before backwards, and rather less in thickness. Each testis or testicle is placed within the cavity of the scrotum in such a manner that its long axis is directed upwards, slightly forwards, and outwards. The left testis occupies a somewhat lower level than the right. The testis (Fig. 751) has two somewhat flattened surfaces, one of which, called the *outer surface* (facies lateralis), looks outwards and backwards; while the other, or *inner surface* (facies medialis), looks inwards and forwards. These two surfaces are separated by two rounded borders. Of these the *anterior border* (margo anterior) is the more convex, and is free, while the *posterior border* (margo posterior) is less rounded, and is the one by which the organ is suspended within the scrotum. To the posterior border is attached a structure called the **epididymis**, and also the lowest portion of the **spermatic cord.** Each border ends

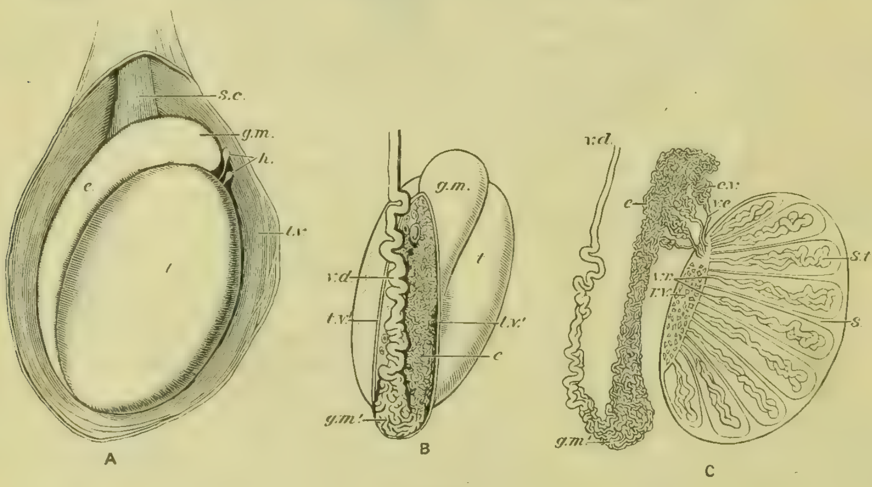


Fig. 751.

A. The right testis and epididymis, seen within the tunica vaginalis, which has been opened up.
B. The right testis and epididymis seen from behind, after complete removal of the parietal portion of the tunica vaginalis.
C. Diagram to illustrate the structure of the testis and epididymis.

c.v. Coni vasculosi.	*r.v.* Rete testis.	*t.v.* Tunica vaginalis.
e. Epididymis.	*s.* Septula testis.	*t.v'.* Cut edge of tunica vaginalis.
g.m. Globus major.	*s.c.* Spermatic cord.	*v.d.* Vas deferens.
g.m'. Globus minor.	*s.t.* Seminiferous tubule.	*v.e.* Vas efferens.
h. Hydatids.	*t.* Testis.	*v.r.* Tubuli recti.

above in the *upper* and below in the *lower extremity* of the testis (extremitas superior et extremitas inferior). Owing to the obliquity of the long axis of the gland, the upper extremity of the testis lies on an anterior and external plane to the lower one.

Epididymis.—In connexion with the testis is the epididymis, which is composed of the first much convoluted portion of the duct of the gland. The epididymis is a somewhat crescentic structure, curved round the posterior border,

and overlapping, to some extent, the posterior part of the outer surface of the testis. The upper, somewhat swollen part of the epididymis, is called the **globus major** (caput epididymidis), and overhangs the upper end of the testis, to which it is directly connected by numerous emerging ducts, by connective tissue, and by the serous covering of the organ. The lower and smaller end is termed **globus minor** (cauda epididymidis), and is attached by loose areolar tissue and by the serous covering to the lower end of the testis. The intermediate part or **body** (corpus epididymidis) is applied against, but is separated from, the posterior part of the outer surface of the testis by an involution of the serous covering of the organ, which forms an intervening pocket termed the digital fossa.

Attached to the globus major, or to the adjoining part of the upper extremity of the testis, there are usually one or two minute pedunculated bodies, called **hydatids** of the epididymis or of the testis (appendices testis), which have a developmental interest. Above the globus major, and in front of the lower part of the spermatic cord, there is also sometimes a small body present, called the **organ of Giraldes** or **paradidymis.** This is rarely seen in the adult.

Tunica Vaginalis.—The cavity within which the testis and its epididymis are placed is lined by a smooth serous membrane—the tunica vaginalis—which resembles in appearance and structure the peritoneum from which it is originally derived. The cavity is considerably larger than the contained structures, and extends not only down to a lower level than the testis, but also reaches upwards to a higher level than the gland. The sac or cavity tapers as it is traced upwards, and above the level of the testis the spermatic cord bulges forwards into its posterior part. The tunica vaginalis not only lines the cavity for the testis, but is reflected from the posterior wall of the scrotal chamber over the testis and epididymis, giving a covering to each. The part of the membrane lining the cavity is called the **parietal portion** (lamina parietalis) of the tunica vaginalis, while the part clothing the testis and epididymis is the **visceral portion** (lamina visceralis). Between the outer surface of the testis and the body of the epididymis, the visceral part of the tunica vaginalis dips in and lines an interval called the **digital fossa** (sinus epididymidis). On the other hand, the tunica vaginalis is absent where the globus major and globus minor of the epididymis are adherent to the testis, and similarly the serous covering is incomplete posteriorly, where the various structures forming the spermatic cord enter or leave the testis and epididymis. From the lower part of the testis or epididymis a small crescentic fold of the tunica vaginalis passes downwards to the bottom of the sac.

Structure of the Testis and Epididymis.—Beneath the serous tunica vaginalis the testis is invested by an external coat, composed of dense white inelastic fibrous tissue called the **tunica albuginea**, from the deep surface of which a number of slender fibrous bands or septa dip into the gland. These—the **septula testis**—imperfectly divide the organ into a number of parts called **lobes** or **lobules** (lobuli testis, Fig. 751). All the septa end posteriorly in a mass of fibrous tissue which is directly continuous with the tunica albuginea, and which projects forwards into the testis along its posterior border. This structure receives the name of **mediastinum testis**, or **corpus Highmori.** The mediastinum is traversed by an exceedingly complicated network of fine canals, into which the minute tubules which compose the substance proper of the testis open. The mediastinum is also pierced by the arteries, veins, and lymphatics of the testis. These vessels enter the posterior border of the organ, and traversing the mediastinum, spread out on the fibrous septa which radiate towards all parts of the deep surface of the tunica albuginea. In this way a delicate network of vessels (tunica vasculosa) is formed on the deep surface of the tunica albuginea and on the sides of the septa.

The testis is composed of enormous numbers of much convoluted **seminiferous tubules** (tubuli seminiferi contorti), which fill up the intervals between the septa. These minute tubules look like fine threads to the unaided eye, and are but loosely connected together. Usually but three or four are found in each lobule of the gland, and the total number of tubules in the testis has been estimated at about 600. The seminiferous tubules, after a course of about two feet in length, pass towards the mediastinum testis, and unite, at acute angles, to form a smaller

number of slender tubes which run a straight course. These latter are called **tubuli recti**, and open into the complicated canal network of the mediastinum, which has received the name **rete testis.**

Microscopic sections show that the walls of the seminiferous tubules are composed of a firm basement membrane and of an epithelial lining, formed of several layers of cells. Certain cells of this epithelium are constantly undergoing transformation into **spermatozoa**, and the appearance of a tubule in section varies much, according to the greater or less activity of its epithelial cells.

The secretion of the seminiferous tubules is carried through the tubuli recti into the rete testis, and leaves the latter, to reach the canal of the epididymis, through from fifteen to twenty minute tubules called **vasa efferentia** (ductuli efferentes testis). These latter tubules pierce the tunica albuginea and enter the globus major, which is in direct contact with the upper end of the testis. Each vas efferens is at first straight, but soon becomes much convoluted, and forms a little conical mass called a **conus vasculosus**. Within the globus major the little twisted canals finally open into the single much convoluted tube which constitutes the

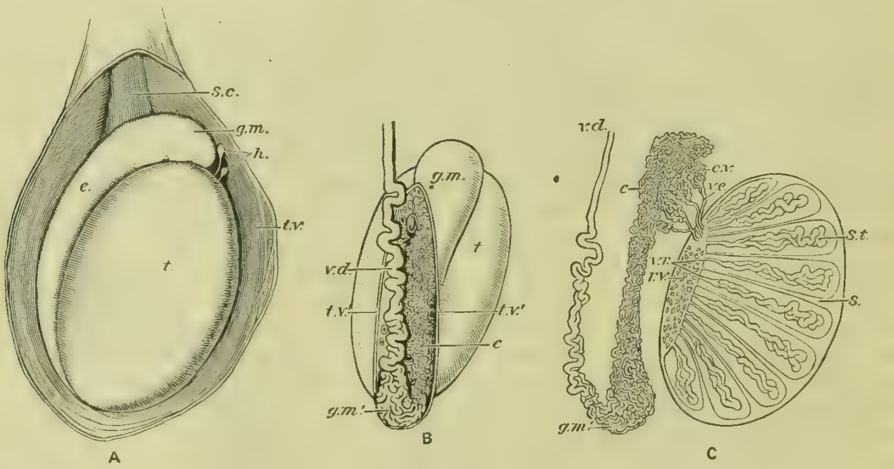


FIG. 752.

A. The right testis and epididymis, seen within the tunica vaginalis, which has been opened up.
B. The right testis and epididymis seen from behind, after complete removal of the parietal portion of the tunica vaginalis.
C. Diagram to illustrate the structure of the testis and epididymis.

c.v. Coni vasculosi.	*r.v.* Rete testis.	*t.v.* Tunica vaginalis.
e. Epididymis.	*s.* Septula testis.	*t.v'.* Cut edge of tunica vaginalis.
g.m. Globus major.	*s.c.* Spermatic cord.	*v.d.* Vas deferens.
g.m'. Globus minor.	*s.t.* Seminiferous tubule.	*v.e.* Vas efferens.
h. Hydatids.	*t.* Testis.	*v.r.* Tubuli recti.

chief bulk of the epididymis, and is called the **canal of the epididymis** (ductus epididymidis). This canal, which is not less than 19 or 20 feet in length, may be said to begin in the globus major, and to end, after an extraordinarily tortuous course, at the globus minor by becoming the vas deferens (ductus deferens, Fig. 752).

In most cases one or more slender convoluted diverticula from the canal of the epididymis may be found near its lower end. These receive the name of **vasa aberrantia** (ductuli aberrantes), and one of them which is very constantly present often measures a foot or more in length.

Minute Structure.—The canal of the epididymis and the vasa efferentia are lined by a ciliated epithelium, the cilia of which maintain a constant current towards the vas deferens. The canal of the epididymis possesses a muscular coat composed of an inner stratum of transversely and an outer stratum of longitudinally directed fibres. The wall, at first thin, becomes much thicker as the canal approaches the vas deferens.

Vessels and Nerves of the Testis.—The testis is supplied by the **spermatic artery**, a branch of the aorta. This slender vessel, after a long course, reaches the posterior border of the testis,

where it breaks up into branches which enter the mediastinum testis, and are distributed along the septa and on the deep surface of the tunica albuginea. The **veins** issuing from the posterior border of the testis form a dense plexus, called the **plexus pampiniformis**, which finally pours its blood through the spermatic vein, on the right side, into the inferior vena cava; on the left side, into the left renal vein. The **nerves** for the testis accompany the spermatic artery, and are derived from the **aortic** and **renal plexuses**. The arteries and nerves of the testis communicate with those on the lower part of the vas deferens, namely, with the artery of the vas and with twigs from the hypogastric plexus. The **lymphatic vessels** of the testis pass upwards in the spermatic cord, and end in the lumbar lymphatic glands.

THE VAS DEFERENS.

The **vas deferens** (ductus deferens) is the direct continuation of the canal of the epididymis. Beginning at the lower extremity of the epididymis, it ends, after a course of nearly 18 inches, by opening as the **common ejaculatory duct** into the prostatic or first part of the urethra. The duct in parts of its course is somewhat convoluted, and the actual distance traversed by it is not more than 12 inches. Placed in the first instance outside the abdominal cavity, the vas deferens ascends within the scrotum towards the lower part of the anterior abdominal wall, which it reaches not far from the middle line. During this part of its course the duct, together with the vessels and nerves of the testis, is surrounded by a number of loose coverings derived from certain layers of the abdominal wall, and the cord-like structure so formed is termed the **spermatic cord**. The vas deferens, together with the accompanying vessels and nerves, now passes through the abdominal wall in an oblique passage, to which the name **inguinal canal** is applied. Within the abdomen the vas lies immediately beneath the peritoneum, and soon crossing over the pelvic brim, it enters the pelvis, on the side wall of which it proceeds backwards towards the base of the bladder. Here, near the middle line, the vas deferens is joined by the duct of the corresponding **vesicula seminalis**, and the common ejaculatory duct, thus formed, having traversed the prostate, opens into the urethra.

At first the vas deferens, like the canal from which it takes its origin, is very tortuous, but soon increasing in thickness, the duct becomes less twisted, and passes upwards along the inner side of the epididymis and behind the testis to enter the spermatic cord (Fig. 752). Its course is now almost vertically upwards towards the spine of the pubis, near which, crossing the inner part of Poupart's ligament, the vas enters the inguinal canal by the external abdominal ring. Of the structures composing the spermatic cord the vas is the most posterior, and it can be readily distinguished, even in the undissected subject, by its hard firm feel when it is taken between the finger and thumb. In the inguinal canal the vas is directed outwards, upwards, and a little backwards to the internal abdominal ring, where, at a point half-an-inch above Poupart's ligament, and midway between the symphysis pubis and the anterior superior iliac spine, it enters the abdomen. The distance between the point where the cord enters the inguinal canal to the point where it leaves it to enter the abdomen is about one and a half inches. While passing from the external to the internal abdominal ring the vas deferens, together with the other structures of the spermatic cord, rests upon the upper grooved surface of Poupart's ligament, and is placed behind the aponeurosis of the external oblique and some of the lower fibres of the internal oblique muscle. From before backwards the vas rests, in the first instance, upon the conjoined tendon of the internal oblique and transversalis muscles, and further outwards upon the transversalis fascia. Above the cord are some arching fibres of the internal oblique muscle, which enter the conjoined tendon. As the vas deferens leaves the inguinal canal by the internal abdominal ring, it turns round the deep epigastric artery on its outer and posterior aspect. Completely changing the direction of its course, the duct now runs for a short distance backwards, inwards, and upwards, beneath the peritoneum to a point one and a half to two inches from the spine of the pubis, where it crosses the ilio-pectineal line and enters the pelvis. In this part of its course the duct usually at first lies in front of the external iliac vessels, and then in the floor of a little triangular fossa between the vessels and the pelvic brim. On the side wall of the pelvis the vas is continued backwards, and a little downwards and inwards, in the direction of the ischial spine, and lies immediately beneath the peritoneum, through which it can

usually be seen shining. In the pelvic part of its course the vas deferens crosses on the inner side of (1) the obliterated hypogastric artery, (2) the obturator nerve and vessels, (3) the vesical vessels, and (4) the ureter (Fig. 753).

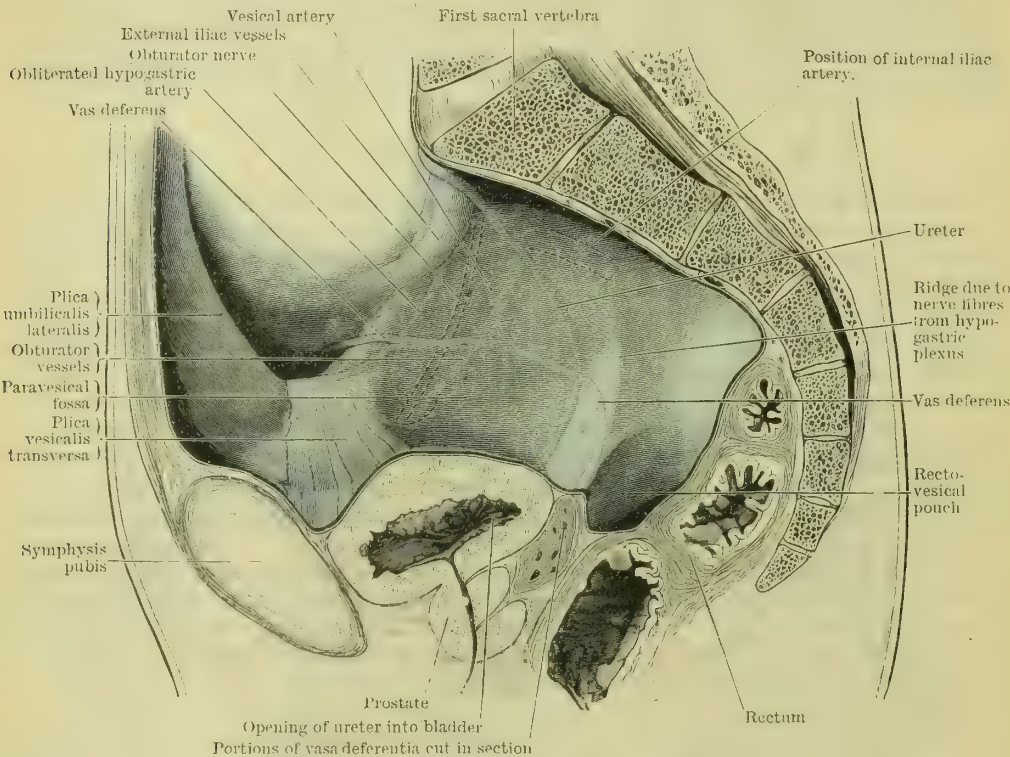


Fig. 753.—Mesial Section of an Adult Male Pelvis.

The coils of the small intestine which lay within the pelvis have been lifted out in order to give a view of the side wall of the pelvic cavity. The peritoneum is coloured blue. The separation of the bladder from the prostate is indicated somewhat diagrammatically.

Beyond the ureter the vas takes a somewhat sudden bend, and passes downwards and inwards towards the middle line, beneath the peritoneum of the pelvic floor. Reaching the interval between the base of the bladder in front and the rectum behind, the vasa deferentia of opposite sides occupy the angle formed between the vesiculæ seminales (Fig. 755). As they approach one another each vas becomes somewhat tortuous, sacculated, and dilated, and assumes a general resemblance in structure to a portion of the vesicula seminalis. To this dilated part of the vas deferens the term **ampulla** (ampulla ductus deferentis) is applied. As it turns inwards the vas lies a short distance behind the ureter, and immediately in front of the edge of the peritoneal fold sometimes known as the posterior false ligament of the bladder. Just above the base of

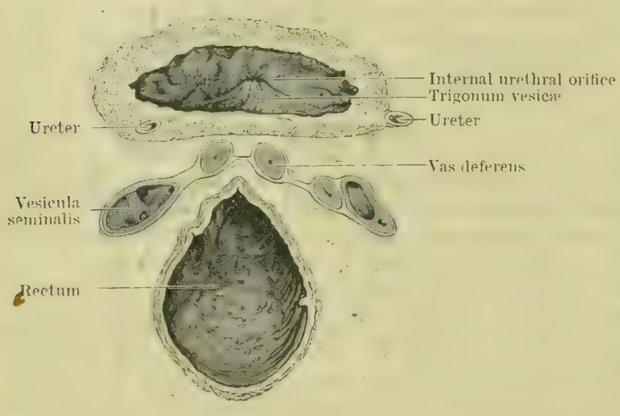


Fig. 754. — Horizontal Section through the Rectum and Bladder at the Level at which the Ureters pierce the Bladder Wall.

From a specimen in the Museum, Trinity College, Dublin.

the prostate the vas deferens becomes once more a narrow canal, and is joined by the duct of the corresponding seminal vesicle to form the **common ejaculatory duct**, which, after a short course downwards and forwards through the prostate, opens into the urethra.

In some cases the vas deferens crosses the obliterated hypogastric artery before it enters the pelvic cavity; it normally does so in the fœtus.

Common Ejaculatory Duct (ductus ejaculatorius).—This duct, formed by the union of the vas deferens with the duct of the corresponding seminal vesicle, is less than one inch in length, and lies very close to its fellow of the opposite side as it passes

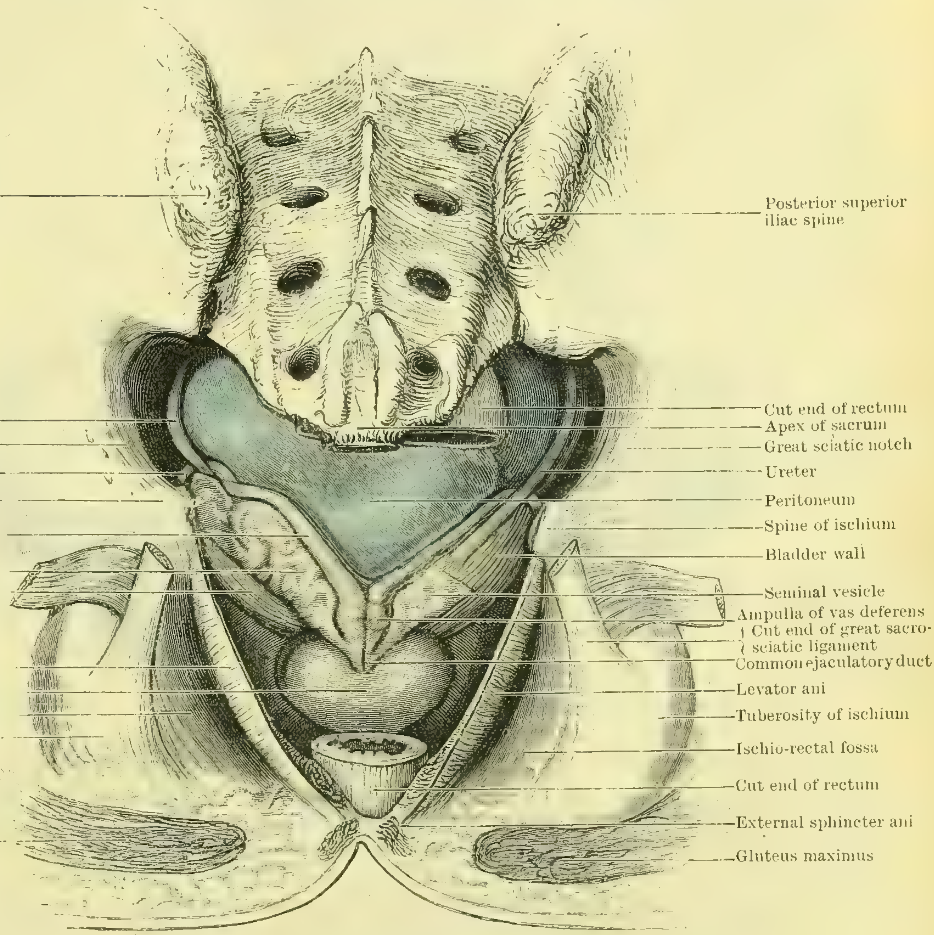


FIG. 755.—VIEW OF THE BASE OF THE BLADDER, PROSTATE, SEMINAL VESICLES, AND VASA DEFERENTIA FROM BEHIND.

The coccyx and sacro-sciatic ligaments, together with the muscles attached to them, have been removed. The levatores ani have been separated along the median raphe, and drawn outwards. A considerable portion of the rectum and the upper part of the right seminal vesicle have been taken away. The recto-vesical pouch of peritoneum is coloured blue.

through the prostate behind its mesial lobe. The ducts open by slit-like apertures into the first part of the urethra on each side of the **sinus pocularis** (utriculus prostaticus).

Seminal Vesicles.—The vesiculae seminales, or seminal vesicles, are a pair of hollow sacculated structures placed in front of the rectum and behind the bladder (Fig. 755). Each vesicula seminalis is usually about two inches in length, and has its long axis directed downwards, inwards, and somewhat forwards. The upper extremity of the vesicle, which is partly covered by peritoneum, is large and rounded, and lies at a considerable distance from the middle line, behind the lower end of the ureter. The vesicle tapers towards its lower end, which is placed

close to the middle line and immediately above the prostate. Inferiorly, the vesicle becomes constricted to form a short duct (ductus excretorius), which joins the outer side of the corresponding vas deferens at an acute angle to form the common ejaculatory duct. The inner side of each vesicle is related to the vas deferens, and the outer side, when the bladder is empty, lies close to the sloping pelvic floor. The seminal vesicle often assumes a more vertical position when the bladder is distended, a more horizontal one when the bladder is empty. Its upper end is sometimes found to be curved backwards against the side of the rectum. The seminal vesicles are in some cases much smaller than usual, and may be even less than one inch in length. They are often unsymmetrical.

The seminal vesicles are more intimately related to the wall of the bladder than to that of the rectum—their upper ends are separated from the rectum by a portion of the recto-vesical pouch of peritoneum, while lower down the septum of fascia which intervenes between the vesiculæ seminales and the rectum is denser than that which separates them from the bladder. The vesicula seminalis is in reality a tube bent in a tortuous manner on itself, and if the dense connective tissue which envelops it be taken away, the length of the tube when untwisted may be found to be as much as five inches. The tube is closed above, and a number of short tortuous branches come off it at different levels. The development of the vesiculæ seminales shows that they are to be looked upon as diverticula of the vasa deferentia, from which they originally arise as small pouches.

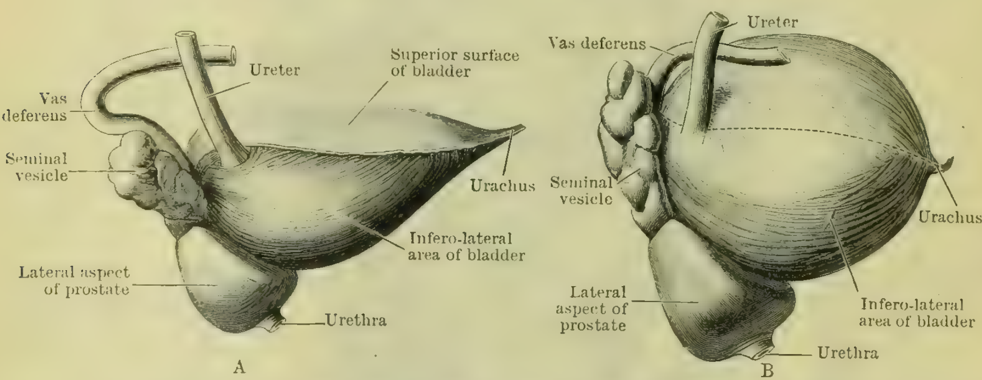


FIG. 756.—THE BLADDER, PROSTATE, AND SEMINAL VESICLE VIEWED FROM THE SIDE. Drawn from specimens hardened *in situ*.

In A the bladder contained but a small amount of fluid ; in B the quantity was somewhat greater.

The dense tissue in which the seminal vesicles are embedded contains much unstriped muscle, which, sweeping round in the side wall of the recto-vesical pouch, gains an attachment to the fascia in front of the sacrum. The large veins coming from the prostatic and vesical plexuses are closely related to the seminal vesicles.

Structure of the Vas Deferens and Vesicula Seminalis.—Except near its termination, where it is dilated to form the ampulla, the vas deferens is a thick-walled tube with relatively a very small lumen. The hard cord-like sensation which the vas deferens conveys to the touch is due to the thickness and toughness of its wall, which is composed of three layers—an outer **fibrous** (tunica adventitia), an intermediate **muscular** (tunica muscularis), and an inner **mucous coat** (tunica mucosa). The thickness of the wall is due to the great development of the middle or muscular coat, which is composed of an inner layer of circularly and an outer layer of longitudinally directed unstriped muscular fibres. Near the beginning of the vas there is an inner longitudinal layer also. The mucous membrane of the vas exhibits a few longitudinal folds. The ampulla, or terminal part, possesses much thinner walls, and, as the surface of its mucous membrane has a number of ridges separating depressed areas, the lining of the tube presents a pitted or honeycombed appearance. The wall of the vesicula seminalis resembles that of the ampulla in being thin, and in having a mucous lining with uneven honeycomb-like ridges and depressions. In the wall of the seminal vesicle the same coats are to be recognised as in the vas, but the muscular stratum is much thinner.

Vessels and Nerves of the Vas and Vesicula Seminalis.—The vas receives its arterial supply from the superior or inferior **vesical arteries.** The **artery to the vas** accompanies that structure, supplying it as far as the testis, where it ends by anastomosing with branches of the spermatic artery. The vesicula seminalis is supplied by the inferior vesical artery. The nerves of the vas and vesicula seminalis are derived from the hypogastric plexus.

Descent of the Testis.

The peculiar course pursued by the vas deferens in the adult, and the manner in which it is related to the anterior abdominal wall, are rendered clear by a study of the arrangement of the parts that obtains in the fœtus. The testes until nearly the end of intra-uterine life are placed in the abdominal cavity. Lying at first on the posterior wall of the abdomen, in the neighbourhood of the kidney, the testis is held in place by a fold of peritoneum, which forms for it a mesentery called the **mesorchium.** As growth goes on the testis is found to occupy a lower level in the abdominal cavity, and in the seventh month it lies near the internal abdominal ring. Meanwhile a blind pouch or diverticulum of the peritoneal membrane, termed the **processus vaginalis**, has grown downwards and inwards through the anterior abdominal wall towards the scrotum, deriving as it goes a covering from each of the layers of the abdominal wall through which it passes. The testis with its mesorchium enters the diverticulum of the abdominal cavity, and in this manner reaches the scrotum. At a later stage, the connexion between the part of the processus vaginalis that lies in the scrotum and the peritoneal lining of the abdomen becomes lost by the obliteration of the upper part of the pouch. Thus the part of the processus vaginalis that persists in the scrotum becomes the parietal portion of the tunica vaginalis; while the visceral part of that membrane is the primitive peritoneal covering of the testis and epididymis (Figs. 757 and 758).

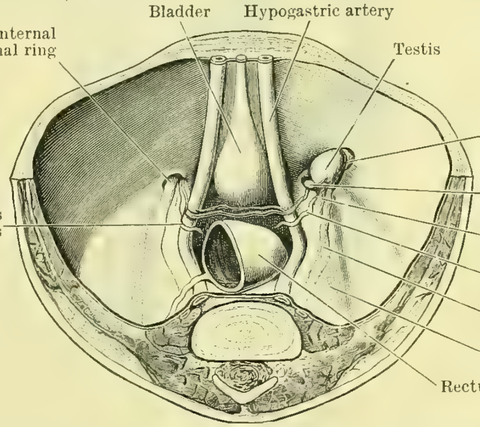


Fig. 757.—View looking from above into the Pelvis and Lower Part of the Abdominal Cavity in a Fœtus of about the Seventh Month.

On the left side, which represents a slightly more advanced condition than the right, the testis has entered the inguinal canal; on the right side the testis is still within the abdominal cavity.

Often a small fibrous band—the **ligamentum vaginale**—may be found in the adult passing through the inguinal canal and joining the peritoneum superiorly in the region of the internal abdominal ring. Sometimes the ligament is connected below with the tunica vaginalis, but more often it does not reach so far downwards.

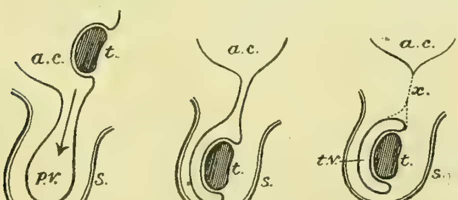


Fig. 758.—Diagram to illustrate the descent of the testis and the manner in which the tunica vaginalis is derived.

a.c. Abdominal cavity. *s.* Scrotum.
p.v. Processus vaginalis. *t.v.* Tunica vaginalis.
t. Testis. *x.* Ligamentum vaginale.

When present it represents the obliterated portion of the processus vaginalis (rudimentum processus vaginalis). In other rare cases the processus vaginalis may persist after birth as a channel freely open to the abdominal cavity above, or the passage, becoming closed at intervals, may give rise to one or more cysts within the coverings of the spermatic cord.

It sometimes happens that the descent of the testis is arrested, and then, either failing to enter the processus vaginalis, the testis remains within the abdominal cavity; or entering the processus vaginalis, it fails to reach the scrotum, and lies in the inguinal canal. The term cryptorchism is frequently applied to such cases.

In connexion with the descent of the testis a remarkable cord-like structure—the

gubernaculum testis—must be mentioned. The gubernaculum in its earliest condition is represented by a peritoneal fold stretching downwards from the caudal end of the ridge which higher up gives origin to the testis. At a later stage this fold is relatively much shorter, and is found to contain between its layers fibrous and muscular tissue. The gubernaculum, when it is at its greatest development (about the sixth month), is rounded and cord-like, and is attached above to the lower end of the testis, while inferiorly it is fixed near the inguinal region. The muscular fibres which it contains are derived by an ingrowth from the muscles of the inguinal part of the anterior abdominal wall. As the testis enters the processus vaginalis the gubernaculum atrophies, but its muscular fibres are supposed to give origin, in part at least, to the cremaster muscle of the adult. The connective tissue and smooth muscle fibres, which connect the testis with the lowest part of the scrotum in the adult, are also derived from the gubernaculum. It is considered by some anatomists that the movement downwards of the testis may be partly due to the shrinking of the gubernaculum as it atrophies (Fig. 757).

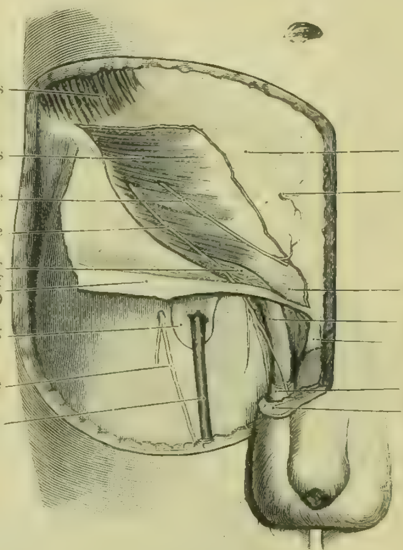


FIG. 759.—THE GROIN. The structures seen on removal of part of the obliquus externus (A. M. Paterson).

In some mammals, such as the elephant, the testes remain permanently within the abdominal cavity; while in others, such as the rabbit and the hedgehog, the peritoneal pouches remain widely open throughout life, and the testes are periodically withdrawn into the abdomen.

THE SPERMATIC CORD.

The testis in its course downwards through the abdominal wall into the scrotum takes with it its duct (vas deferens), its vessels, and its nerves of supply. All these lie together in the inguinal canal as they traverse the abdominal wall, and when they leave the canal by the external abdominal ring they extend downwards to the posterior border of the testis. The vas deferens, the spermatic vessels, and the nerves and lymphatics of the testis, loosely connected together, form the spermatic cord (funiculus spermaticus). At the internal abdominal ring the constituent parts of the cord disperse and separate from each other. The cord may therefore be considered to extend from the internal abdominal ring to the posterior border of the testis. The structures which form the cord are enclosed within a number of coverings derived from the layers of the anterior abdominal wall. When the constituents of the cord reach the posterior border of the testis, the coverings surround the tunica vaginalis and its enclosed testis, and so form a part of the wall of the scrotum. The coverings of the cord derived from the abdominal wall are three in number, and are named intercolumnar fascia, cremasteric fascia, and infundibuliform fascia. The **intercolumnar fascia** is the most superficial of the three coverings, and is derived from the aponeurosis of the external oblique muscle, with which it is continuous round the margins of the external abdominal ring. The **cremasteric fascia** consists partly of muscular fibres derived from the lower part of the internal oblique muscle, and partly of delicate connective tissue. The muscular fibres pass down over the cord, and form a series of loops round the testis and tunica vaginalis. The **infundibuliform fascia** is derived from the fascia transversalis of the abdomen. It passes

downwards over the cord and encloses its various structures, together with a certain amount of areolar tissue derived from the sub-peritoneal tissue of the abdominal wall (Figs. 759 and 760).

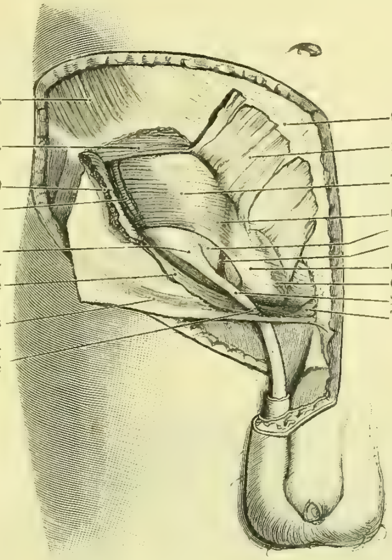


FIG. 760.—THE GROIN. The structures seen on reflexion of part of the obliquus internus (A. M. Paterson).

In addition to the structures enumerated above, the artery to the vas, the cremasteric artery, and the genital branch of the genito-crural nerve, accompany the structures forming the spermatic cord.

THE SCROTUM.

The **scrotum,** in which the testes are placed, varies much in appearance in different subjects, and even in the same individual, at different times. As the result of cold or of exercise, the wall of the scrotum becomes contracted and firm, and the skin covering it wrinkled; at other times the wall may be relaxed and flaccid, the scrotum then assuming the appearance of a pendulous bag. The left side of the scrotum reaches to a lower level than the right, in correspondence with the lower level of the testis on that side of the body. The skin covering the scrotum is of a darker colour than the general skin of the body, and is covered by hair. The difference in the appearance of the scrotum at different times is due to the amount of contraction or relaxation of a layer of muscular fibres placed in the superficial fascia. When this muscular layer is contracted, the skin is thrown into folds or wrinkles called rugæ; when it is relaxed, the skin becomes more smooth and even. This muscular tissue is called the **dartos muscle.** The scrotum is marked in the middle line by a median **raphe** (raphe scroti), which is continued backwards towards the anus, and forwards on to the under, or urethral, surface of the penis. The interior of the scrotum is divided into two cavities, one for each testis, by an incomplete **septum** (septum scroti), which is in part continuous with deeper layers of the dartos tissue. The wall of each of these cavities is formed by the corresponding tunica vaginalis, infundibuliform fascia, cremasteric fascia, and intercolumnar fascia, while the skin, the superficial fascia, and dartos muscle form coverings which are common to the whole scrotum, and enclose both cavities. In the superficial fascia of the scrotum there is an entire absence of fat.

The scrotum in the fœtus contains no cavity, but, like the labia majora in the female, it is composed entirely of vascular connective tissue.

Vessels and Nerves of the Scrotum.—The scrotum receives its vascular supply from the **superficial perineal branches** of the internal pudic arteries which reach its posterior surface, and from the **external pudic branches** of the femoral artery which reach its upper and anterior part. The nerves of the scrotum are derived from the **superficial perineal branches** of the internal pudic, from the **perineal branch** of the small sciatic, and from the **ilio-inguinal nerve.** The

branches from the internal pudic and sciatic nerves reach the scrotum from behind, while the ilio-inguinal supplies its upper and anterior part.

THE PENIS.

The **penis** is composed chiefly of erectile tissue, and is traversed by the canal of the urethra. The surface nearest to which the canal of the urethra lies is called the **under** or **urethral surface** (facies urethralis); the opposite and more extensive aspect is the **dorsum penis.** The erectile tissue is for the most part disposed in three longitudinal columns, which in the body of the organ are placed side by side, while at the root of the penis they separate from one another, and become attached to the triangular ligament and pubic arch. Two of these masses of erectile tissue, placed one on each side of the middle line, and forming the dorsum and sides of the penis, are called the **corpora cavernosa** (corpora cavernosa

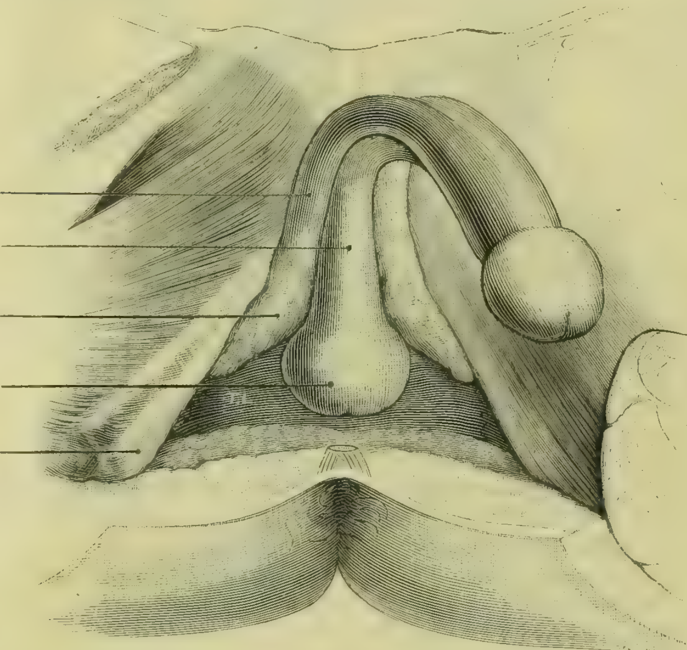


Fig. 761.—Dissection to illustrate the Component Parts of the Penis.
On the right side of the figure the muscles of the thigh have been reflected down to the plane of the obturator externus. The letters TL are placed upon the triangular ligament.

penis), while the third, which is called the **corpus spongiosum** (corpus cavernosum urethræ), is situated mesially near the urethral surface. The corpus spongiosum is the part of the penis which is traversed by the urethra, and it is considerably smaller than the corpora cavernosa which form the chief bulk of the organ.

In the **body of the penis** (corpus penis) each corpus cavernosum is placed close to the mesial plane, and presents a rounded surface, except where it is flattened and in contact with its fellow of the opposite side. The corpora cavernosa are separated on the anterior (dorsal) surface by a shallow groove, and on the posterior (urethral) aspect by a deeper and wider furrow, in which lies the corpus spongiosum (Fig. 762). Towards the distal end of the penis the corpus spongiosum becomes expanded, and, spreading towards the dorsal surface of the organ, forms a kind of conical cap which covers over the blunt rounded terminations of the corpora cavernosa. The terminal expansion of the corpus spongiosum is termed the **glans penis**, and is traversed by the urethra. The prominent margin of the glans, called the **corona glandis,** projects dorsally and laterally beyond the extremities of the corpora cavernosa. The slit-like opening at the summit of the glans, where the urethra terminates, is termed the **meatus urinarius**, or external urethral orifice,

Each corpus cavernosum ends in a blunt conical extremity, the apex of which is received into a hollow in the base of the glans. The skin covering the body of the penis is thin, delicate, and freely movable, and, except near the root of the organ, is free from hairs. On the urethral aspect of the penis the skin is marked by a median raphe, continuous with the raphe of the scrotum. Reaching the base of the glans, the skin forms a free fold called the **prepuce** (præputium), which overlaps the glans to a variable extent. From the deep surface of the prepuce the skin is reflected on to the terminal part of the penis, just above the level of the corona glandis, and is continued over the entire glans to the meatus urinarius. A small fold, the **frenulum præputii**, passes to the deep surface of the prepuce from a point just below the meatus urinarius. The skin covering the glans is firmly attached to the underlying erectile tissue, and here, as well as on the deep surface of the prepuce, it presents some resemblance to mucous membrane.

Minute sebaceous glands (glandulæ præputiales) are found on the glans and inner surface of the prepuce; the secretion from these helps to form the **smegma præputii**, which tends to collect in the groove between the glans and the prepuce.

At the **root of the penis** (radix penis) the three component parts of the organ separate from one another (Fig. 761). The corpora cavernosa, diverging from each other laterally, at first become somewhat swollen, and then gradually tapering off, gain a fibrous attachment to the inner part of the pubic arch. These diverging parts of the corpora cavernosa are called the **crura penis**, and each is covered by the corresponding ischio-cavernosus muscle. The corpus spongiosum lying between the crura becomes enlarged, and forms a somewhat spherical mass which receives the name **bulb of the urethra** (bulbus urethræ). The bulb varies much in size in different individuals, and is attached to the under surface of the triangular ligament, against which it rests. The posterior part and under surface of the bulb usually show a median notch or groove, which is an indication that the bulb is originally composed of two symmetrical portions, fused in the middle line. These two portions are termed the **hemispheria bulbi urethræ**, and are best seen in subjects whose tissues have been hardened by intra-vascular injections. Covering the superficial surface of the bulb is the bulbo-cavernosus muscle. The canal of the urethra, piercing the triangular ligament, enters the bulb a short distance in front of its posterior extremity (Fig. 765).

A somewhat triangular band of strong fibrous tissue, called the **suspensory ligament of the penis**, is attached to the front of the symphysis pubis, and extends to the fibrous capsule of the penis, with which it becomes continuous (Fig. 759).

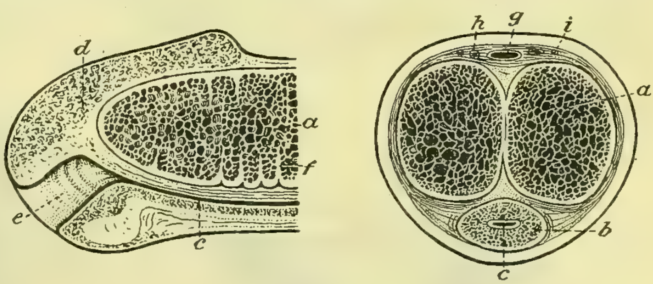


Fig. 762.—A Longitudinal Section of the Terminal Portion of the Penis, and a Transverse Section through the Body of the Organ.

a. Corpus cavernosum. *b.* Corpus spongiosum. *c.* Urethral canal. *d.* Glans penis. *e.* Fossa navicularis. *f.* Part of septum pectiniforme. *g.* Dorsal vein. *h.* Dorsal artery. *i.* Dorsal nerve.

Structure of the Penis.—Each corpus cavernosum penis is enclosed by a dense fibrous coat or **tunica albuginea** (tunica albuginea corporum cavernosorum), which, fusing with the corresponding coat of the opposite side, forms a mesial septum (septum penis). The septum is very incomplete, especially near the terminal part of the penis, where it is interrupted by a number of nearly parallel slit-like perforations, hence the term **septum pectiniforme** is often applied to it. Through these openings the erectile tissue of the corpora cavernosa of opposite sides is continuous.

The fibrous coat contains many elastic fibres, and may be divided into an outer layer of longitudinally directed fibres and an inner layer of circular fibres, some of which latter are continued into the septum. Numerous fibrous strands, called **trabeculæ** (trabeculæ corporum cavernosorum), proceed from the deep surface of the tunica albuginea, and stretching across the interior of the corpus cavernosum, form a fine sponge-like framework

whose interspaces communicate freely with one another, and are filled with blood. These blood-containing spaces lead directly into the veins of the penis, and like the veins have a lining of flat endothelial cells. The size of the penis varies with the amount of blood in this cavernous tissue. The structure of the corpus spongiosum resembles that of the corpora cavernosa, but the fibrous coat is much thinner, and the trabeculæ are finer. Smooth muscle fibres surround the urethra as it traverses the corpus spongiosum (Fig. 762).

In some mammals, such as the walrus, dog, bear, baboon, etc., a bone called the **os penis** is developed in the septum which intervenes between the corpora cavernosa.

Vessels and Nerves of the Penis.—The penis receives its arterial supply from branches of the internal pudic artery. The erectile tissue of the corpora cavernosa is supplied chiefly by the **deep arteries of the penis**, while that of the corpus spongiosum receives its arterial supply from the **artery to the bulb.** Branches of the **dorsal artery** of the penis piercing the fibrous coat of the corpora cavernosa furnish additional twigs to the erectile tissue of these structures. The glans receives its chief blood supply from branches of the dorsal artery. The small branches of these arteries run in the trabeculæ of the erectile tissue, and the capillaries, into which they lead, open directly into the cavernous venous spaces. As they lie in the finer trabeculæ, the smaller branches often present a peculiar twisted appearance, and hence the name **helicine arteries** (arteriæ helicinæ) is sometimes applied to them.

The veins with which the cavernous spaces communicate carry the blood, for the most part, either directly into the **prostatic plexus**, or into the **dorsal vein**, and so to the prostatic plexus. The dorsal vein of the penis begins in tributaries from the glans and prepuce, and lies in the groove between the corpora cavernosa as it ascends to pass beneath the sub-pubic ligament and join the prostatic plexus. On each side of it lies the dorsal artery, and still further from the middle line the dorsal nerve (Fig. 762).

The nerve-supply of the penis is derived from the internal pudic nerve and from the **hypogastric plexus** The branches of the internal pudic are the **dorsal nerve** of the penis, and branches from the **superficial perineal nerves.** These supply the cutaneous structures of the penis, while the sympathetic filaments from the hypogastric plexus, which reach the penis through the prostatic plexus, end in the erectile tissue.

THE PROSTATE.

The **prostate** (prostata) is a partly glandular, partly muscular organ of a dark brown-red colour which surrounds the beginning of the urethra in the male. It lies within the pelvis, and is enclosed by a dense capsule derived from the pelvic fascia. The common ejaculatory ducts traverse the prostate in their course downwards and forwards to join the urethra as it descends through the gland (Fig. 755). The size of the prostate varies considerably in different individuals, but its transverse or longest diameter is usually from one and a quarter to one and a half inches, its antero-posterior diameter about three quarters of an inch, and its vertical diameter about one and a quarter inches. Superficially the prostate is

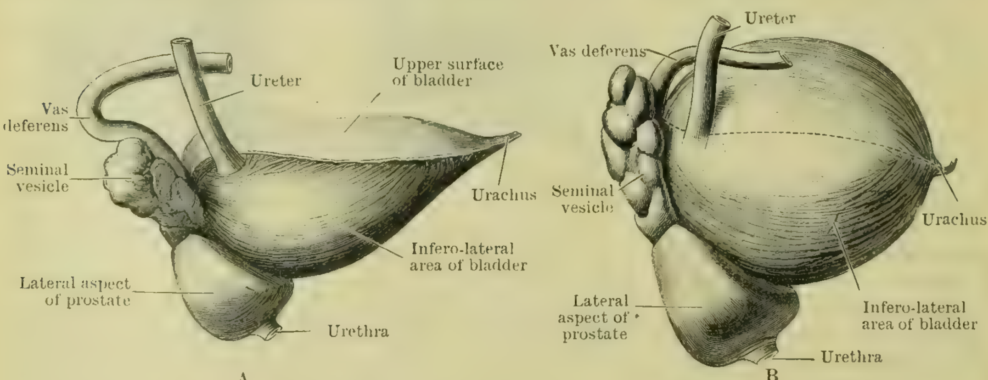


FIG. 763.—BLADDER, PROSTATE, AND SEMINAL VESICLES VIEWED FROM THE OUTER SIDE. Drawn from specimens hardened *in situ*.

separated from the bladder by deep wide lateral grooves directed downwards and forwards, and by a narrow posterior groove which is horizontal.

In connexion with the prostate we describe an apex which is directed downwards, a base looking upwards, a posterior, and two lateral surfaces. The general outline of the organ has been often compared with that of a Spanish chestnut.

The upper surface, or **base** of the prostate (basis prostatæ), is directed upwards against the under aspect of the bladder, in the neighbourhood of its urethral opening. The greater part of this surface is structurally continuous with the bladder wall, the separation of the two organs being purely artificial. A narrow portion of the superior surface is, however, free on each side, and forms the lower limit of the deep groove which marks the separation of the bladder and prostate (Fig. 763). The **lateral surface** of the prostate is convex and prominent, especially in its posterior and upper portion, and rests against the fascia covering the levator ani muscle. The lateral surfaces are directed for the most part outwards, downwards, and somewhat forwards, and meet together in front in a rounded anterior border, often called the "**anterior surface**" (facies anterior) of the prostate. Posteriorly the prostate presents a flattened triangular area, directed backwards and downwards against the anterior wall of the rectum, from which it is separated by a layer of the pelvic fascia. This flattened **posterior surface** (facies posterior) is separated on each side from the lateral surface by a rounded border which, beginning above at the prominent lateral part of the prostate, ends below at the apex of the organ. The **apex** of the prostate (apex prostatæ) points downwards, and is in relation to the deep or superior layer of the triangular ligament. From the apex the rounded anterior border, which separates the lateral surfaces, passes upwards in the middle line behind the symphysis pubis and retropubic pad of fat. This border is interrupted in its lower part by the passage of the urethra.

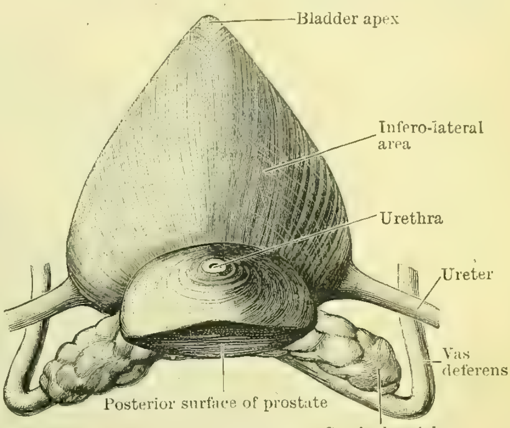


FIG. 764.—PROSTATE, BLADDER, AND SEMINAL VESICLES SEEN FROM BELOW.

Drawn from a specimen hardened *in situ*. The lateral surfaces of the prostate are seen one on each side of the urethra and in front of the posterior surface.

The urethra enters the prostate at a point near the middle of its upper surface, and leaves it at a point situated on its anterior border, just above and in front of the apex. As it descends, the urethra describes a curve which is concave forwards, and in mesial section it is seen to lie nearer to the posterior surface than to the anterior border of the gland.

The common ejaculatory ducts, entering the prostate at the border which separates the base from the posterior surface, run downwards, inwards, and forwards, to open into the prostatic portion of the urethra very close to one another. The somewhat wedge-shaped portion of the prostate, which lies between these ducts and the posterior aspect of the urethra, receives the name of **middle lobe** (lobus medius, Fig. 766). The base of this middle lobe projects upwards against the bladder, and is continuous with the part of the bladder wall lying immediately behind the urethral orifice. When hypertrophied (as it often is in old people) the middle lobe of the prostate may cause a considerable elevation in the cavity of the bladder, to which the term uvula vesicæ is applied, and which possesses considerable surgical interest. The rest of the prostate is described as being composed of two large lateral portions or **lateral lobes**, which are, however, not marked off from one another superficially.

The prostate is surrounded in front and laterally by a plexus of large veins which lies embedded within its capsule, and is called the **prostatic venous plexus.**

Structure of the Prostate.—The greater bulk of the prostate is composed of unstriped muscle fibres. The muscular tissue not only forms the outer layers of the prostate, but it also sends into the deeper parts numerous processes which spread through the whole structure as a network, in the meshes of which the glandular part of the organ is contained. Posteriorly some of the muscle fibres are continuous with those of the bladder. The glandular tissue (corpus glandulare) of the prostate, which is practically confined to the part of the organ which lies

behind the plane of the urethra, lies embedded among the muscle fibres, and is composed of minute, slightly branched tubules, lined by a columnar epithelium. In the upper portion of the gland the tubules are slightly dilated and shorter than in other parts, where they are long and convoluted. The glandular tubules lead into the minute prostatic ducts, which open into the urethral canal as it traverses the prostate. These ducts (ductus prostatici) are numerous—about twenty in all —and open for the most part into a groove on each side of the median elevation (crista urethralis) in the posterior wall of the urethra (Fig. 767).

Vessels and Nerves of the Prostate.—The prostate receives it blood supply from branches of the **hæmorrhoidal** and **inferior vesical arteries**, while the large plexus of veins which surrounds it, and into which the veins of the penis open, drains into the **vesical plexus.** In old people the veins of the prostatic plexus usually become much enlarged. The nerves of the prostate are derived from the **hypogastric plexus.**

COWPER'S GLANDS.

Cowper's glands (glandulæ bulbo-urethrales) are a pair of small bodies placed in relation to the second, or membranous, part of the urethra. They are each about

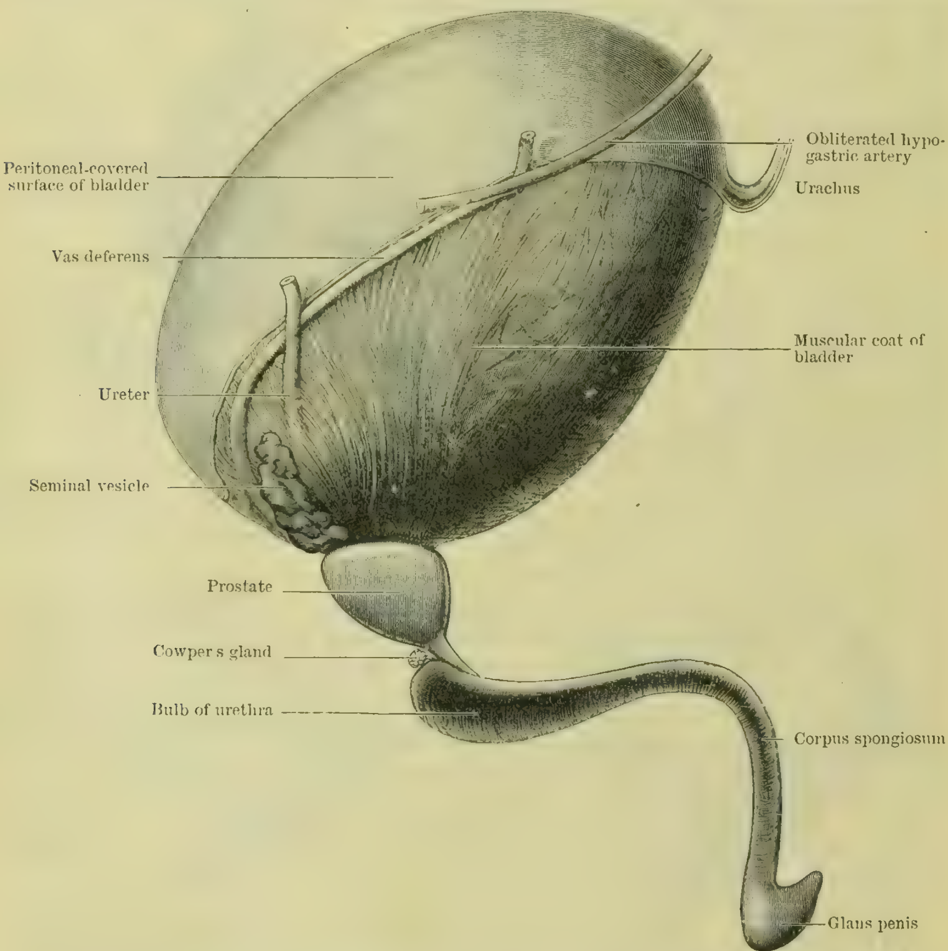


FIG. 765.—THE BLADDER AND THE STRUCTURES TRAVERSED BY THE URETHRA, seen from the outer side after removal from the body. The bladder has been artificially distended.

the size of a pea, and are of a yellowish-brown colour. Situated in the space between the two layers of the triangular ligament, they lie below the level of the apex of the prostate, and above that of the bulb of the corpus spongiosum (Figs. 765 and 767). The gland is made up of a number of closely applied lobes or

lobules, and is of the compound racemose type. The ductules of each gland unite to form a single duct (ductus excretorius), which pierces the bulb of the corpus spongiosum, and, after a relatively long course, ends by opening into the spongy portion of the urethra by a minute aperture. The secreting acini are lined by columnar epithelium.

The glands receive their arterial supply from the artery to the bulb.

In old age these glands may be difficult or impossible to find.

THE MALE URETHRA.

The **urethra** in the male is a channel of about eight inches in length leading from the bladder to the external urethral orifice at the extremity of the glans penis. The canal serves not only for the passage of urine, but it also affords an exit for the seminal products which enter by the common ejaculatory ducts, and for the secretion of the prostatic and Cowper's glands. In addition, numerous minute glands (glandulæ urethrales) pour their secretion into the urethra.

The first part of the urethra lies within the pelvic cavity, and has an almost

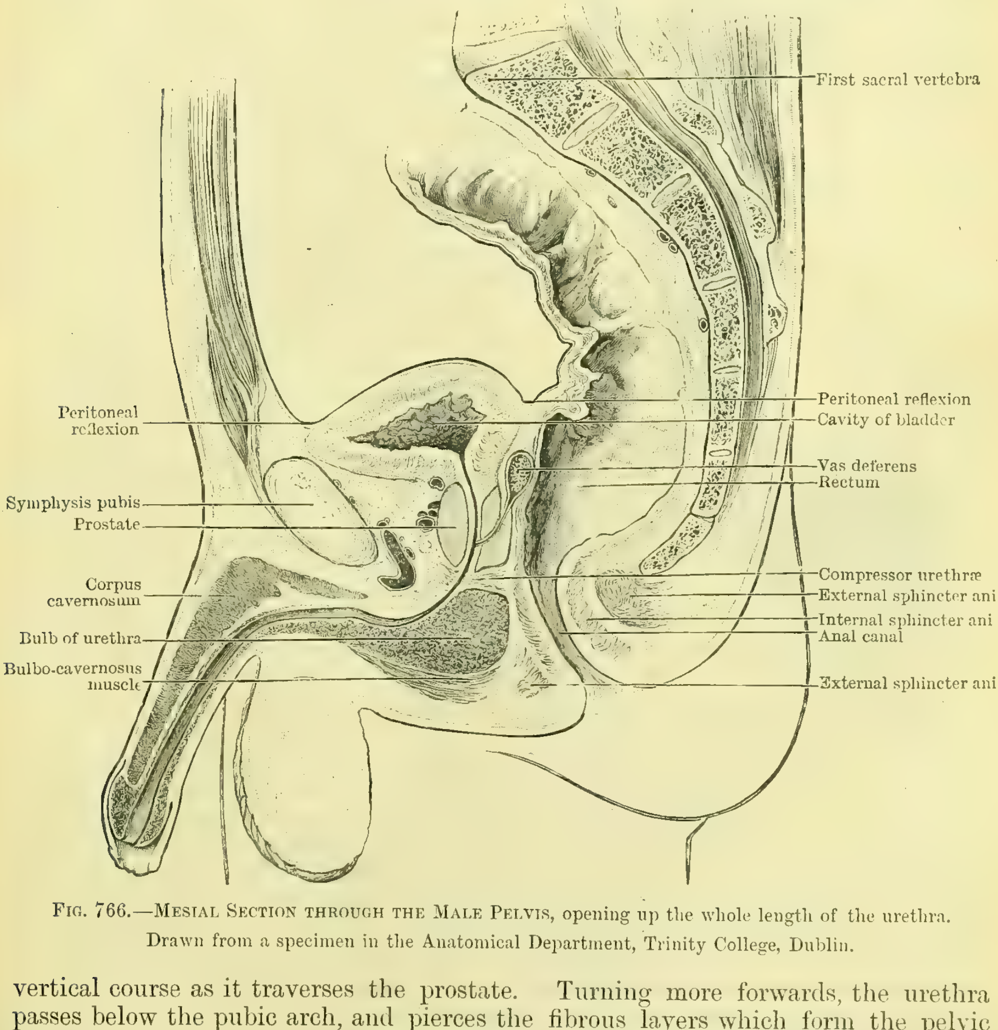


Fig. 766.—Mesial Section through the Male Pelvis, opening up the whole length of the urethra. Drawn from a specimen in the Anatomical Department, Trinity College, Dublin.

vertical course as it traverses the prostate. Turning more forwards, the urethra passes below the pubic arch, and pierces the fibrous layers which form the pelvic wall in this region. Leaving the pelvic cavity, the canal enters the bulb of the corpus spongiosum, where the latter is attached to the triangular ligament, and throughout the rest of its course it lies surrounded by the erectile tissue of the corpus spongiosum and glans penis. The part of the urethra which lies embedded in

the prostate is called the **prostatic portion** ; the short portion which pierces the pelvic wall is the **membranous portion,** and the part surrounded by the corpus spongiosum receives the name of **spongy portion.** Of these three sections of the urethra the spongy portion is much the longest, and the membranous is the shortest.

Prostatic Portion of the Urethra. — The prostatic part (pars prostatica) of the urethra descends through the prostate from the base towards the apex, describing a slight curve which is concave forwards. It is about one inch in length, and is narrower above and below than in its middle portion, which, is indeed the widest part of the whole urethral canal. Except while fluid is passing, the canal is collapsed, and the mucous membrane of the anterior and posterior walls is in contact, and thrown into a series of longitudinal folds. When distended, the middle, or widest part of the canal, may normally have a diameter of about one-third of an inch. The posterior wall, often termed the "floor" of the prostatic urethra, presents a distinct mesial ridge or elevation, called the **crista urethræ** (crista urethralis) or **verumontanum** (Fig. 767). This projects forwards into the urethra to such an extent that the canal presents in transverse section a crescentic outline. In the depressions or grooves on each side of the crista urethræ the numerous ducts of the prostatic glands open by minute apertures. Some few ducts from the middle part of the gland open in the middle line, either just above or just below the urethral crest. On the summit of the crista urethræ is a slit-like opening which leads backwards and upwards for a distance of about a quarter of an inch, as a blind pouch, in the substance of the prostate. This little cavity is the **prostatic utricle** (utriculus prostaticus) or **sinus pocularis,** and represents the uterus and vagina of the female, being developed from the fused posterior ends of the Müllerian ducts. On each side of the mouth of the utricle is the much more minute opening of the common ejaculatory duct. When traced upwards towards the bladder, the urethral crest, diminishing in height, becomes indistinct, but in some cases it can be traced as far as the uvula vesicæ. When followed in the opposite direction the ridge becomes less marked, and can be followed on the urethral wall into the membranous portion of the canal, where it divides into a pair of slight folds or elevations (Fig. 767).

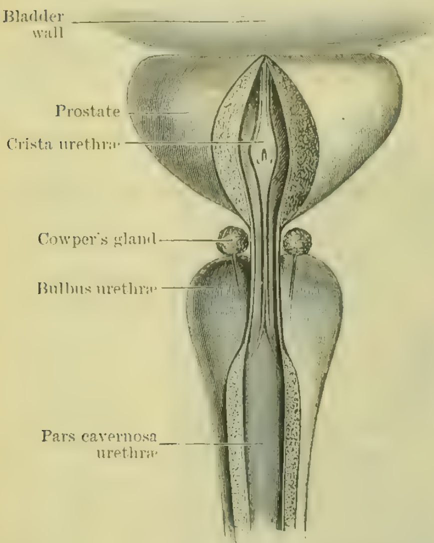


FIG. 767. — THE PROSTATIC, MEMBRANOUS, AND UPPER PORTION OF THE SPONGY URETHRA, opened from in front and above to show the posterior wall or floor. The minute openings of the common ejaculatory ducts and the orifice of the sinus pocularis are seen upon the crista urethræ.

Membranous Part of the Urethra. — The second or membranous portion (pars membranacea) of the urethra leads downwards and forwards from the apex of the prostate to the bulb of the corpus spongiosum, and is the shortest and narrowest of the three subdivisions of the canal, its length being somewhat less than half an inch. It begins at the deep layer of the triangular ligament, where it is continuous with the prostatic portion, and ends by piercing the superficial layer, to become continuous with the spongy portion of the urethra. Placed in front of the rectum, it lies about one inch behind and below the sub-pubic ligament, and is surrounded by fibres of the compressor urethræ muscle. Behind it, on each side of the mesial plane, are Cowper's glands. The membranous part of the urethra enters the bulb at a point somewhat in front of its posterior extremity, and, owing to the oblique direction of the canal as it joins the bulb, the anterior, or upper wall, of the passage is longer than the posterior wall or floor (Fig. 765). Further, the posterior part of the bulb projects so much backwards that it overlaps to a considerable extent the posterior wall of the second part of the urethra.

A slight median elevation, which is continuous above with the crista urethræ, projects into the canal from its posterior wall, and becoming less marked as it is traced downwards, is often seen to divide into two faint ridges. When the canal is empty other longitudinal folds or ridges are usually to be seen on the mucous membrane, but these become obliterated when the passage is distended.

The terminal portion of the membranous urethra, where it is overlapped posteriorly by the urethral bulb, lies in front of the triangular ligament. It is considerably wider than the upper part of this subdivision of the canal, and is very thin-walled (Figs. 765 and 766).

Spongy Portion of the Urethra.—The third or spongy portion (pars cavernosa) of the urethra is much the longest of the three subdivisions. It begins at a point about half-an-inch in front of the posterior end of the bulb, and ends at the external orifice on the glans penis. Its proximal portion has a fixed position and direction, while its distal part varies with the position of the penis. The canal is about six inches in length, and is surrounded throughout its whole extent by the erectile tissue of the corpus spongiosum and glans. Directed at first forwards through the bulb of the corpus spongiosum, the canal turns downwards and forwards at the point where it comes to lie in front of the lower part of the symphysis pubis (Fig. 766). This bend in the direction of the canal, roughly speaking, corresponds to the place of attachment of the suspensory ligament to the dorsum of the penis. When the penis is drawn upwards towards the front of the abdomen, the direction of the terminal half of the canal is of course changed, and at the same time the whole length of this subdivision of the urethra becomes more uniformly curved. The urethra as it enters the bulb lies at first in the upper part of the erectile tissue, but as it passes forwards it sinks deeper, and comes to occupy the middle part of the corpus spongiosum (Fig. 766). In the glans, on the other hand, most of the erectile tissue lies in the dorsal and lateral aspects of the urethra. Like the other parts of the urethra, the canal is closed except during the passage of fluid, the closure being effected by the apposition of the dorsal and ventral walls of the passage, except in the part of the canal which lies in the glans penis, where the lateral walls of the canal come into contact (Fig. 768). Thus the first part of the canal, when empty, is represented in cross section by a transverse slit, and the terminal part by a vertical slit. The spongy part of the urethra does not present a uniform calibre throughout, but is narrower in its intermediate part, where it traverses the corpus spongiosum, than it is in those portions of its course which are surrounded by the bulb and the glans. The terminal dilated part of the passage is termed the **fossa navicularis urethræ**, and opens on the surface by the vertically-placed slit-like **external urethral orifice** (orificium urethræ externum), which is bounded by lateral lips, and is the narrowest and least dilatable part of the whole urethral canal.

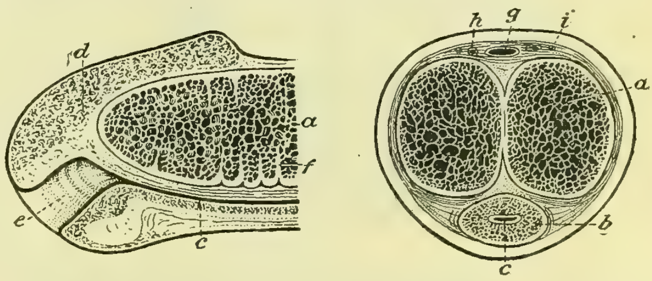


FIG. 768.—A LONGITUDINAL SECTION OF THE TERMINAL PORTION OF THE PENIS, AND A TRANSVERSE SECTION THROUGH THE BODY OF THE ORGAN.

a. Corpus cavernosum. *d*. Glans penis. *g*. Dorsal vein.
b. Corpus spongiosum. *e*. Fossa navicularis. *h*. Dorsal artery.
c. Urethral canal. *f*. Part of septum pectiniforme. *i*. Dorsal nerve.

The ducts of Cowper's glands open by very minute apertures in the under wall of the proximal part of the spongy portion of the urethra. Before opening into the canal, they lie for some distance immediately beneath its mucous membrane. A number of little pit-like recesses, called the **lacunæ urethrales**, also open into the spongy part of the urethra, and are so disposed that their openings lead obliquely into the canal in the direction of its external orifice.

In some cases a somewhat valve-like fold of the mucous membrane is found in the upper wall of the urethra in the region of the fossa navicularis.

Structure.—The superficial cells of the mucous membrane lining the urethra are columnar as far as the fossa navicularis, where they become replaced by squamous epithelial cells. Except near the terminal part of the canal, the mucous membrane contains numerous minute mucous glands, called **glands of Littré** (glandulæ urethrales), the ducts of which open into the urethra. Beneath the mucous membrane is an exceedingly vascular layer, which is surrounded by a coat of unstriped muscle, continuous superiorly with the muscular tissue of the prostate and bladder. The erectile tissue of the corpus spongiosum is placed immediately outside the muscular coat of the canal. A small amount of erectile tissue is also present surrounding the membranous urethra.

THE FEMALE REPRODUCTIVE ORGANS.

The reproductive glands in the female consist of a pair of **ovaries** placed laterally in the cavity of the pelvis. In connection with each ovary is an elongated passage or tube—the **Fallopian tube**—leading to the uterus, into the cavity of which it opens. There is no direct continuity between the ovary and the Fallopian tube, such as exists between the other glands of the body and their ducts, but the ova produced in the ovary pass into the open end of the tube, and are thus conducted to the uterine cavity. The **uterus**, or **womb**, is a hollow muscular organ which occupies a nearly median position in the pelvis; it is joined by the Fallopian tubes above, and it communicates with the upper part of the vagina below. The ovum, having passed through the Fallopian tube, reaches the cavity of the uterus, and in it, if fertilisation takes place, the ovum undergoes its development into embryo and fœtus. The **vagina** is the passage leading from the uterus to the exterior. Its external opening lies behind that of the urethra, within the urogenital space. In connection with the urogenital space are a number of structures which are included under the term **external genital organs**, and which represent in the female the various parts of the penis and scrotum in the male. These are the

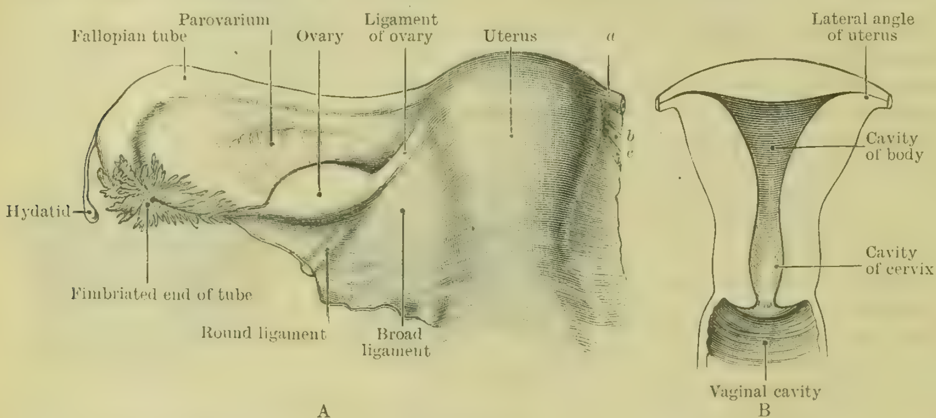


FIG. 769.—A. THE UTERUS AND BROAD LIGAMENT SEEN FROM BEHIND (the broad ligament has been spread out).

a, *b*, and *c*, the isthmus tubæ, the ligament of the ovary, and the round ligament of the right side cut short.

B. DIAGRAMMATIC REPRESENTATION OF THE UTERINE CAVITY OPENED UP FROM IN FRONT.

labia majora and the **mons Veneris**, the **labia minora**, the **clitoris**, and the **bulbus vestibuli**. The **glands of Bartholin**, placed one on each side of the lower part of the vagina, are accessory organs of the female reproductive system, and represent Cowper's glands in the male.

THE OVARY.

The **ovary** (ovarium) is a solid body, flattened from side to side, and about the size and shape of a large almond. In the adult the ovary is placed against the side wall of the pelvic cavity, and is connected by peritoneal folds with the broad ligament of the uterus and with the lateral wall of the pelvis. Although these

ligaments of the ovary do not hold the organ firmly fixed in any definite place, still the position occupied by the ovary within the pelvic cavity is fairly constant. The length of the ovary is usually between one and one and a half inches, and the thickness from side to side between a quarter and half-an-inch.

In the ovary we recognise two poles or extremities—an *upper pole*, larger and more rounded than the somewhat pointed *lower pole*. The term **tubal pole** (extremitas tubaria) is applied to the upper end of the ovary, as it is most intimately connected with the Fallopian tube; the term **uterine pole** (extremitas uterina) is used with reference to the lower extremity, since this part of the ovary is connected with the uterus by a fibrous cord, termed the ligament of the ovary. The flattened *surfaces* of the ovary are called *internal* (facies medialis) and *external* (facies lateralis), and the *borders* separating them *anterior* (margo mesovaricus) and *posterior* (margo liber). The posterior border is convex and free; while the anterior one, which is straighter and narrower, is connected by a very short peritoneal fold (mesovarium) with the posterior layer of the broad ligament of the uterus. The vessels and nerves enter the ovary by this anterior border, which is therefore often termed the **hilus** of the ovary.

Position and Relations of the Ovary.—When the ovary occupies its most usual position the long axis of the gland is vertical. Its outer or lateral surface

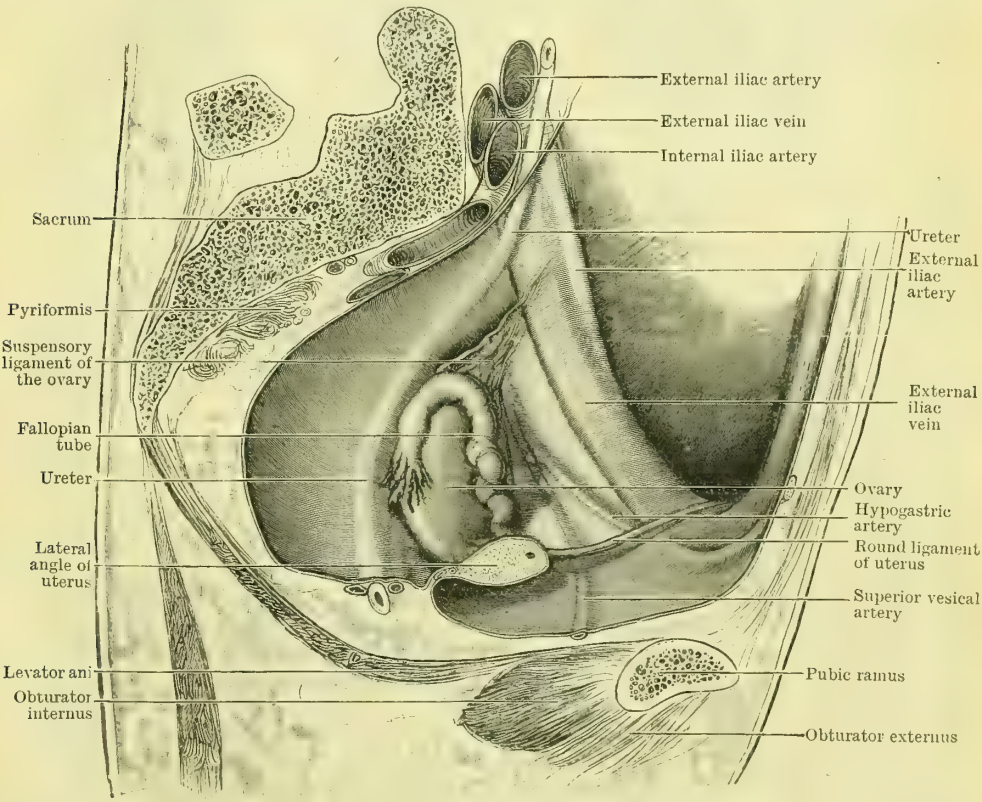


FIG. 770.—SIDE WALL OF THE FEMALE PELVIS, showing the position of the ovary and its relation to the Fallopian tube. The pelvis has been cut in section parallel to, but at some distance from, the mesial plane. Drawn from a specimen in the Anatomical Department, Trinity College, Dublin.

lies against the side wall of the pelvis, and its inner surface looks inwards towards the pelvic cavity. The peritoneum of the pelvic wall, where the ovary lies against it, is depressed to form a little fossa termed the **fossa ovarica**, within which the ovary is placed. The upper pole of the ovary lies below the level of the external iliac vessels, and its lower end is placed just above the level of the peritoneum covering the pelvic floor. The fossa ovarica, in which the ovary lies, extends as far forwards as the obliterated hypogastric artery, and backwards as far as the

ureter and uterine vessels. Thus the anterior border of the ovary lies just behind the line of the obliterated hypogastric artery, and the posterior border is on a plane anterior to the ureter (Fig. 770). The inner surface of the ovary is almost completely covered by the Fallopian tube, which, passing upwards on it near its anterior border, arches over the upper pole, and then turns downwards in relation to the posterior border and posterior part of the inner surface (Fig. 770).

In some cases the ovary is found to lie behind, or more rarely in front, of the fossa described above, and its long axis may be oblique instead of vertical. The above description, however, corresponds to the typical position of the organ in women who have not borne children.

Connexions of the Ovary.—When the ovary is in position a small somewhat triangular peritoneal fold passes upwards from its upper pole, and becomes lost in the peritoneum covering the external iliac vessels and the psoas muscle (Fig. 770). This fold has received the name of **suspensory ligament** of the ovary, and is a portion of the upper and outer part of the broad ligament of the uterus, which here contains between its two layers the ovarian vessels and nerves as they pass down into the pelvis to reach the hilus of the ovary. The vessels and nerves entering the ovary along its anterior border are enclosed in a sheath of peritoneum derived from the posterior layer of the broad ligament. In this way the ovary is connected along the whole length of its anterior border by a very short mesentery or **mesovarium** to the posterior aspect of the broad ligament (Fig. 769). The lower pole of the ovary is connected with the lateral angle of the uterus by a ligament called the **ligament of the ovary** (ligamentum ovarii proprium). This has the form of a rounded cord enclosed between the peritoneal folds of the broad ligament, and is attached to the uterus, behind and below the point of entrance of the Fallopian tube. It is chiefly composed of smooth muscle fibres continuous with those of the uterus. The upper pole of the ovary is often directly connected with one of the largest of the fimbriæ surrounding the abdominal end of the Fallopian tube, which receives the name **ovarian fimbria** of the tube (Fig. 769).

Descent of the Ovary.—Like the testes, the ovaries at first lie in the abdominal cavity, and only later assume a lower position. At birth the ovary lies partly in the abdominal, and partly in the pelvic cavity; soon, however, it takes up a position entirely within the pelvis. It is a rare abnormality for the ovary, instead of entering the pelvis, to take a course similar to that of the testis, and pass through the inguinal canal into the tissue of the labium majus.

Structure of the Ovary.—The ovary is for the most part composed of a connective tissue stroma (stroma ovarii), richly supplied by blood-vessels and nerves. The stroma contains very numerous spindle-shaped connective tissue fibres, and some elastic tissue. The surface of the ovary is covered by a layer of epithelium, which is composed of columnar cubical cells, and is continuous with the epithelium of the peritoneum forming the mesovarium. The ovarian epithelium is a persistent portion of the germinal epithelium of the embryo which covers the genital ridges, and from which the ova and other cells of the Graafian follicles are derived. The position in which it becomes continuous with the peritoneum can usually be distinguished as a fine white line near the hilus of the ovary. Shining through the epithelium of the fresh ovary (except in old age), are usually to be seen a variable number of small vesicles—the **Graafian follicles** (folliculi oophori vesiculosi), in which the **ova** are contained. The number of follicles visible, and also the size which each follicle reaches before it ruptures and sheds its contents, is by no means constant. When a follicle ruptures and discharges the ovum its walls at first collapse, but later the cavity becomes filled with extravasated blood and cellular tissue of a yellowish colour. The resulting structure, called a **corpus luteum**, slowly degenerates unless impregnation has taken place, in which case it develops and becomes larger during pregnancy. As it atrophies the cells of the corpus luteum disappear, and the structure, losing its yellow colour, receives the name of **corpus albicans.** Owing to the periodic rupture of the Graafian follicles, the surface of the ovary, which is at first smooth and even, becomes in old age dimpled and puckered.

A section through the ovary, especially in young children, presents in its superficial part a somewhat granular appearance, which is due to the presence of enormous numbers of small follicles, or collections of epithelial cells, embedded in the connective tissue near the surface of the ovary. The larger follicles lie deeper in the stroma, but when they become fully developed they pass towards the surface, where the ripe follicles are

often seen slightly projecting and ready to burst. In the deepest part of the ovary the blood-vessels are most numerous, and here also some smooth muscle fibres are to be found.

The ova and other cells that compose the Graafian follicles are derived originally from the germinal epithelium which covers the developing ovary in the embryo. The epithelium, at first simple, grows down into the underlying tissue in the form of branching tube-like processes, or "egg tubes." This takes place during fœtal development, and the branching cellular processes so formed become broken up, within the stroma, into little nests or clumps of cells, each of which becomes a Graafian follicle. From the beginning

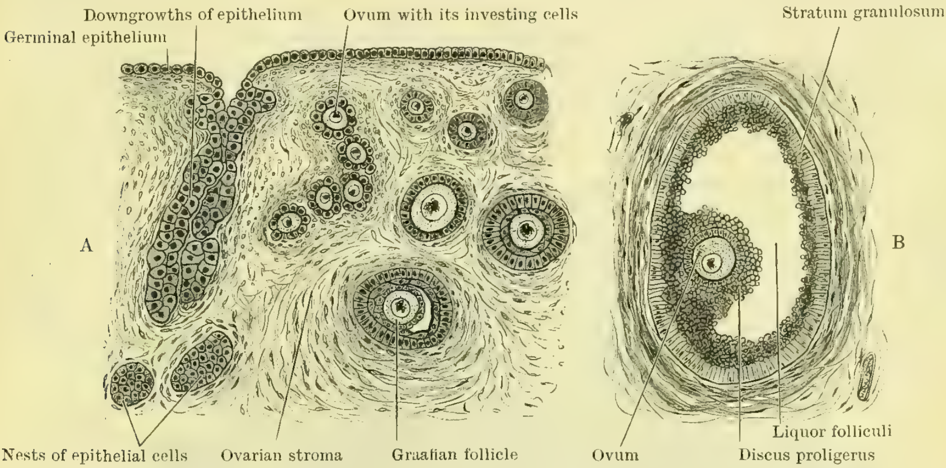


FIG. 771.—A. DIAGRAMMATIC REPRESENTATION OF THE MANNER IN WHICH THE GRAAFIAN FOLLICLES ARISE IN THE DEVELOPING OVARY. B. DIAGRAM ILLUSTRATING THE STRUCTURE OF A RIPE GRAAFIAN FOLLICLE.

some cells of the egg tubes are larger than the others; these become the future ova, while the cells round them become the investing cells of the follicle. The investing cells, at first flattened, form a layer round each ovum. Later becoming columnar, as the follicle increases in size and sinks more deeply in the stroma, these cells divide in such a manner that the ovum becomes surrounded by a double layer of cells. Fluid—**liquor folliculi**—accumulates between the two cellular layers, except at one place where the inner cells surrounding the ovum remain attached to the outer layer or **stratum granulosum.** To the inner cellular mass enclosing the ovum (ovulum) the term **discus proligerus** (cumulus oophorus) is applied (Fig. 771). The ripe follicle contains a relatively large amount of fluid, and the surrounding stroma becomes differentiated to form for each a **capsule** (theca folliculi). This capsule is composed of an inner more *vascular layer* (tunica interna), and an outer more *fibrous layer* (tunica externa). There is reason to believe that in the human embryo the formation of ova and follicles ceases at birth, and that the appearances which have led to the belief that they may originate during the first years of extrauterine life have been due to pathological conditions. In the young child there are enormous numbers of small follicles in the superficial parts of the ovary, but in old age none are found in this situation.

The appearance and structure of the ripe ova have been described on p. 10.

Vessels and Nerves of the Ovary.—The **ovarian arteries,** corresponding to the spermatic arteries of the male, are a pair of long slender vessels which spring from the anterior aspect of the aorta, below the level of origin of the renal vessels. Each gains the pelvis in the fold of peritoneum forming the suspensory ligament of the ovary, and enters the ovary at its anterior border or hilus. These ovarian arteries anastomose freely near the hilus with other vessels derived from the **uterine arteries.** The blood is returned by a series of communicating veins, similar to the **pampiniform plexus** in the male. The **nerves** of the ovary are derived chiefly from a plexus which accompanies the ovarian artery, and which is continuous above with the renal plexus. Other fibres are derived from the lower part of the aortic plexus, and join the plexus on the ovarian artery (plexus arteriæ ovaricæ). The **lymphatics** of the ovary join with those from the upper part of the uterus, and end in the lumbar lymphatic glands.

THE FALLOPIAN TUBES.

The **Fallopian tubes** (tubæ uterinæ) are a pair of ducts or passages which convey the ova, discharged from the Graafian follicles of the ovaries, to the cavity of the

uterus. Each tube is about four and a quarter inches in length, and opens at one end into the pelvic cavity near the ovary, and at the other end by a smaller opening into the lateral part of the uterine cavity. The tube is enclosed in a fold of peritoneum called the **mesosalpinx**, which is a portion of the broad ligament of the uterus.

The opening of the tube into the pelvic cavity—or **ostium abdominale**—is of small size, being only about 2 mm. in diameter when its walls are relaxed, and much narrower when the muscular coat of the tube is contracted. This opening is placed at the bottom of a funnel-like expansion of the tube called the **infundibulum** (infundibulum tubæ uterinæ), the margins of which are produced into a number of irregular processes or **fimbriæ** (fimbriæ tubæ). The presence of these fimbriæ—many of which are branched or fringed—has given the name **fimbriated extremity** to this end of the Fallopian tube. The surface of the fimbriæ which looks into the cavity of the infundibulum is covered by a mucous membrane continuous with that lining the tube, while the outer surface is clothed by peritoneum. The mucous surfaces of the larger fimbriæ present ridges and grooves which are continued into the folds and furrows of the mucous coat of the tube. One of the fimbriæ, usually much larger than the rest, is connected either directly or indirectly with the upper or tubal pole of the ovary, and to it the name **ovarian fimbria** (fimbria ovarica) is applied. The part of the tube continuous with the infundibulum, and into which the ostium abdominale leads, is called the **ampulla** (ampulla tubæ uterinæ). This,

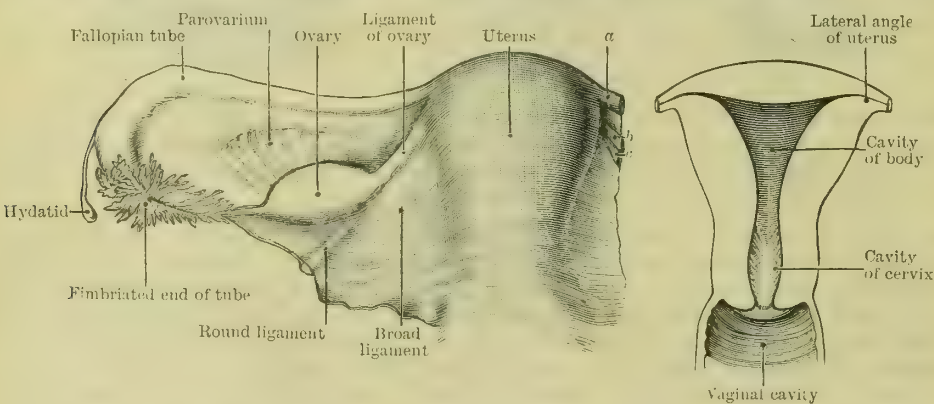


FIG. 772.—A. THE UTERUS AND BROAD LIGAMENT, SEEN FROM BEHIND (the broad ligament has been spread out).
a, *b*, and *c*, the isthmus tubæ, the ligament of the ovary, and the round ligament of the right side cut short.
B. DIAGRAMMATIC REPRESENTATION OF THE UTERINE CAVITY.

the widest and longest portion of the Fallopian tube, is usually tortuous and of varying diameter, being in some places slightly constricted, and in others distended. The wide thin-walled ampulla ends in the narrower, thicker-walled, and much-shorter **isthmus** (isthmus tubæ uterinæ) which joins the lateral angle of the uterus. The last portion of the canal, or **pars uterina**, is embedded in the substance of the uterine wall which it traverses to reach the cavity of the uterus (Fig. 772, B). The opening into the uterus (ostium uterinum tubæ) is smaller than the ostium abdominale, being about 1 mm. in diameter. The lumen of the canal gradually increases in width as it is traced outwards from the uterus.

Course of the Fallopian Tube.—Traced from the lateral angle of the uterus the Fallopian tube is directed at first horizontally outwards towards the lower, or uterine, pole of the ovary. It then passes upwards in relation to the inner side of the anterior border of the ovary, until it reaches the upper or tubal pole, where, arching backwards, it descends along the posterior border, resting against the inner surface of the gland (Fig. 774). As the Fallopian tube describes this loop it often covers almost the entire inner surface of the ovary. The fimbriated end of the tube lies against the lower part of the inner surface of the ovary, and from it the ovarian fimbria passes upwards to gain attachment to the tubal pole.

The fimbriated end of the Fallopian tube lies in the abdominal cavity until the ovary in its descent has entered the pelvis.

Structure of the Fallopian Tubes.—The wall of each tube, which is surrounded by a covering of peritoneum (tunica serosa), is composed of a number of concentric layers, or coats. Immediately beneath the peritoneum is a layer of loose connective tissue in which lie many vessels and nerves (tunica adventitia). Beneath this is the **muscular coat** (tunica muscularis) composed of two strata of smooth muscle fibres,—a more superficial stratum of longitudinally arranged fibres (stratum longitudinale), and a deeper layer the fibres of which are circularly disposed (stratum circulare). Deeper is a **submucous layer** (tela submucosa), and then the lining membrane or **mucous coat** (tunica mucosa). In the part of the tube near the uterus the muscular layer is thicker than towards the other end, and in the isthmus it forms the chief part of the wall. The mucous membrane, on the contrary, is thickest towards the fimbriated end, and here it forms the greater part of the tube wall. The stratum of circular muscle fibres is especially well developed near

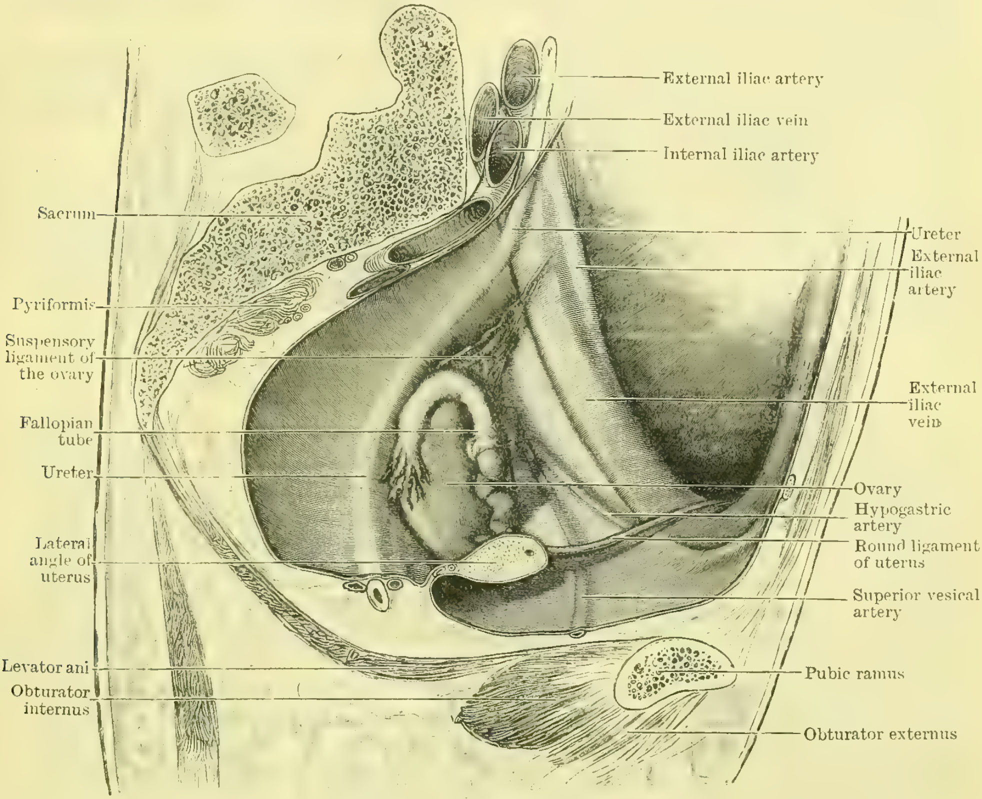


FIG. 773.—SIDE WALL OF THE FEMALE PELVIS, showing the position of the ovary and the course of the Fallopian tube.

The pelvis has been cut in section parallel to, but at some distance from, the mesial plane. Drawn from a preparation in the Anatomical Department, Trinity College, Dublin.

the uterus. The mucous membrane is thrown into numerous longitudinal folds (plicæ tubariæ), which in the ampulla are exceedingly complex, the larger ones being beset on the surface by smaller folds. In transverse sections of this part of the tube the folds of the mucous membrane look like large branching processes projecting into, and almost completely filling up, the lumen of the tube. The mucous membrane is covered by a ciliated epithelium, the cilia of which tend to drive the contents of the tube towards the uterus. The epithelium is continuous with that of the uterus, and at the fimbriated end joins the peritoneum.

Vessels and Nerves of the Fallopian Tube.—The Fallopian tube receives its chief blood-supply from a branch of the **uterine artery** (ramus tubarius), but it also receives small branches derived from the **ovarian artery**. The veins of the tube pour their blood partly into the uterine and partly into the ovarian veins. The **nerves** are derived from the plexus that supplies the ovary, and also from the plexus in connexion with the uterus. The **lymphatics** join the lumbar group of glands.

Epoophoron and Paroophoron.—These are two rudimentary structures found between the layers of the broad ligament.

The **epoophoron** or **parovarium** (sometimes called the organ of Rosenmüller) lies in the mesosalpinx between the Fallopian tube and the ovary. In the adult it consists of a number of small rudimentary blind tubules lined by an epithelium. One of these tubules, called the **duct of Gärtner** (ductus epoophori longitudinalis), lies close and nearly parallel to the Fallopian tube, and is joined by a number of the other tubules (ductuli transversi) which enter it at right angles from the neighbourhood of the ovary. The duct of Gärtner is a persistent portion of the Wolffian duct, and represents the canal of the epididymis in the male, while the tubules which join it are derived from the mesonephros and represent the vasa efferentia and coni vasculosi of the testis (and probably also the ductuli aberrantes of the canal of the epididymis). The epoophoron is best seen by holding up the part of the broad ligament in which it lies to the light.

One or more small, pedunculated, cystic structures, called **hydatids of Morgagni** (appendices vesiculosi), are often seen near the infundibulum of the Fallopian tube. These are usually supposed to represent portions of the upper end of the Wolffian duct.

The **paroophoron** is a collection of rudimentary tubules also enclosed by the layers of the mesosalpinx, but lying nearer the uterus than the epoophoron. These very rudimentary tubules represent the paradidymis or organ of Giraldés, in the male, and are derived from the part of the mesonephros which lies nearer the caudal end of the body of the embryo. The tubules are only easily made out in the child at birth.

THE UTERUS.

The **uterus** or womb is a hollow thick-walled muscular organ placed within the pelvis between the bladder in front and the rectum behind. The ova discharged from the ovary enter the uterus by one of the Fallopian tubes, and if fertilisation takes place, undergo their development within it. In form the uterus is somewhat pear-shaped, the wide upper end of the organ projecting freely upwards and forwards into the pelvic cavity, while the lower more constricted part is connected with the vagina. The usual length of the adult uterus (when non-pregnant) is three inches, its greatest breadth is nearly two inches, and its maximum thickness is about one inch.

In the description of the uterus we distinguish between an upper larger portion, somewhat flattened from before backwards, composed of fundus and body, and a lower more cylindrical part called the cervix (Fig. 774). The part of the uterus that lies above the level of a line joining the points of entrance of the Fallopian tubes is called the **fundus** (fundus uteri). The fundus is convex from before backwards and from side to side, its anterior and posterior aspects being directly continuous with the anterior and posterior surfaces of the body of the organ. The **body** of the uterus (corpus uteri), when seen from in front or from behind, has a somewhat triangular outline, and lies below the fundus, being directly continuous with it. The base of the triangle is directed upwards and formed by a line joining the lateral angles of the uterus, or points of entrance of the Fallopian tubes, while the sides of the triangle correspond to the lateral borders of the uterus, which extend on each side from the lateral angle to the cervix. The *lateral border* (margo lateralis) separates on each side the *anterior surface* (facies vesicalis) from the *posterior surface* (facies intestinalis) of the body. Both these surfaces are rounded, but the posterior is much the more convex. The anterior surface rests against the upper aspect of the bladder, from which it is usually separated only by the layers of peritoneum forming the utero-vesical pouch. The posterior surface forms the chief part of the anterior wall of the deep recess situated between the uterus and rectum, and is usually in contact with some part of the intestine.

The **neck**, or **cervix uteri**, is cylindrical, and at its commencement is marked off from the body by a slight constriction. Its length is about one inch, and its lower end, tapering somewhat, enters the upper part of the vagina. The cervix is attached to

the margin of the opening in the vaginal wall, through which it passes, and in this way a **supravaginal portion** (portio supravaginalis) is marked off from a **vaginal portion** (portio vaginalis) of the cervix. In the vaginal portion of the cervix there is an opening—the **external os uteri** (orificium externum uteri)—through which the cavity of the uterus communicates with that of the vagina. In the uterus which has never been pregnant this opening is nearly circular, but in women who have borne children it is usually a transverse slit with a somewhat irregular outline. In front of and behind this opening the cervix forms two lips, an *anterior* and a *posterior* (labium anterius et labium posterius). The anterior lip is thicker, more rounded, and placed upon a higher level than the posterior lip, which is longer and thinner. The cervix enters the vagina through the upper part of its anterior wall in such a manner that the external os uteri is directed against the upper part of the posterior vaginal wall (Fig. 775).

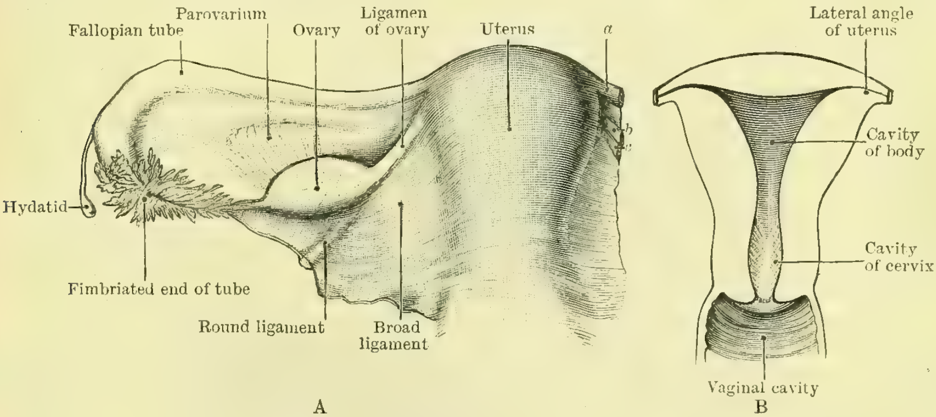


FIG. 774.—A. THE UTERUS AND BROAD LIGAMENT SEEN FROM BEHIND (the broad ligament has been spread out).
a, *b*, and *c*, the isthmus tubæ, the ligament of the ovary, and the round ligament of the right side cut short.
B. DIAGRAMMATIC REPRESENTATION OF THE UTERINE CAVITY OPENED UP FROM IN FRONT.

Cavity of the Uterus.—The cavity of the uterus (cavum uteri) is, owing to the great thickness of the uterine wall, small in comparison with the size of the organ. In the body the cavity is merely a narrow chink between the anterior and posterior walls, which are almost in contact (Fig. 775). When, however, the organ is opened from above downwards in coronal section the cavity of the body has a triangular outline (Fig. 774). The base of the triangle is directed upwards, and corresponds to a line drawn between the openings of the Fallopian tubes, while the apex is directed downwards towards the cervix. The sides of the triangle are convex inwards towards the cavity. The cavity of the body becomes continuous with that of the neck, or cervix, by an opening called the **internal os uteri** (orificium internum uteri), which is a little smaller and more circular than the external os uteri. The cavity of the cervix, or **cervical canal** (canalis cervicis uteri), extends from the internal os uteri, where it joins the cavity of the body, to the external os uteri, where it opens into the vagina. It is a somewhat spindle-shaped passage which is narrower above and below than in its middle part; also sections show that its antero-posterior diameter is shorter than its transverse one, owing to an approximation of its anterior and posterior walls. In the body of the uterus the walls of the cavity are smooth and even, but in the cervical canal the mucous membrane forms a remarkable series of folds, called the **arbor vitæ uterinæ** or **plicæ palmatæ.** These consist of an anterior and a posterior longitudinally directed fold or ridge, from which a large number of secondary folds, or rugæ, branch off obliquely upwards and outwards (Fig. 774).

Connexions of the Uterus and its Relations to the Peritoneum.—In addition to the Fallopian tubes at its upper lateral angles, and the vagina below, the uterus possesses other important connections. Some of these are simply peritoneal folds passing from the uterus to neighbouring structures; others contain fibrous connective tissue, or smooth muscle fibres.

The peritoneum covering the fundus of the uterus is continued down over the anterior surface as far as the junction of the body and cervix, where it leaves the uterus to be reflected on to the bladder, forming the **utero-vesical fold**, or "anterior ligament of the uterus." The peritoneal recess between the bladder and the uterus is called the utero-vesical pouch (excavatio vesico-uterina). Below the level of the floor of this pouch the anterior aspect of the cervix is connected by loose tissue with the posterior or basal part of the bladder. Posteriorly the peritoneum covers the whole of the uterus, except the small portion of the cervix which projects into the upper part of the vagina. The peritoneum covering the posterior surface of the uterus is continued to such a depth that it invests a small portion of the upper part of the posterior wall of the vagina before it is reflected on to the rectum, forming the **recto-vaginal fold** (Fig. 775). The deep pouch between the uterus and vagina in front and the rectum behind is called the **pouch of Douglas** (excavatio recto-uterina), and its entrance is bounded on each side by a crescentic peritoneal fold which passes from the posterior surface of the cervix uteri to the posterior wall of the pelvis, where it ends near the side of the rectum. These crescentic folds are called the **recto-uterine folds** (plicæ recto-uterinæ), or **folds of Douglas**, and each contains between its layers a considerable amount of fibrous and smooth muscular tissue. Some of these fibres, which are continuous with the uterine wall, pass backwards to reach the rectum and constitute the **recto-uterine muscle** (musculus recto-uterinus); others, gaining an attachment to the front of the sacrum, form the **utero-sacral ligament.** In many cases the recto-uterine folds become continuous with one another across the middle line behind the cervix uteri. The peritoneum of the anterior and posterior surfaces, leaving the uterus along each lateral border to reach the side wall of the pelvis, forms the broad ligament of the uterus.

The **broad ligament** (ligamentum latum uteri) is a wide peritoneal fold which passes from the lateral border of the uterus to the pelvic wall, and contains between its layers several important structures (Fig. 774). The plane of the inner part of the ligament is determined by the position of the uterus. When the uterus is normally placed the ligament has an anterior surface which looks downwards as well as forwards, and a posterior one which looks upwards and backwards. Near its attachment to the pelvis the ligament is placed more vertically. The free edge of the ligament contains the Fallopian tube (Fig. 774), and follows the course pursued by that structure. Thus, in the undisturbed condition of parts, it at first passes horizontally outwards towards the lower end of the ovary, where it ascends to arch over the upper pole of the ovary on its inner side. Owing to the course pursued by the Fallopian tube round the ovary, the broad ligament forms a kind of curtain over the gland, and the ovary comes to lie in a little pocket formed by the broad ligament, to which the name of **bursa ovarii** is applied (Fig. 773). This bursa ovarii is not to be confused with the fossa ovarica, or depression in the side wall of the pelvis, against which the ovary is usually placed.

The positions of the various structures in connexion with the broad ligament are most easily demonstrated when the ligament is spread out as flat as possible.

The ovary is connected with the posterior layer of the broad ligament by a very short mesentery, called the **mesovarium,** which, passing to the hilus, encloses the ovarian vessels and nerves. The part of the broad ligament which slings the Fallopian tube is called the **mesosalpinx.** When the ligament is spread out, the mesosalpinx has the form of a narrow triangle, the apex of which is at the lateral angle of the uterus, while the upper side is formed by the Fallopian tube, and the lower one by the ligament of the ovary and the ovary itself. The narrow base of the triangle is directed outwards. Between the layers of this part of the broad ligament are situated the parovarium (epoophoron) and the paroophoron (Fig. 774). The part of the broad ligament below the level of the mesosalpinx is termed **mesometrium,** and contains, especially in its lower part, a considerable amount of fatty connective tissue (parametrium) and unstriped muscle fibres.

The **ligament of the ovary** (ligamentum ovarii proprium) is a rounded fibrous cord, of about one to one and a half inches in length, which is attached by its outer end to the lower pole of the ovary, and by its inner one to the lateral angle of the uterus immediately below and behind the entrance of the Fallopian tube. This

ligament, which is largely composed of unstriped muscle fibres continuous with those of the uterus, is enclosed in a slight fold derived from the posterior layer of the broad ligament.

The ligament of the ovary represents the upper portion of the gubernaculum which appears in the embryo.

The **round ligament** of the uterus (ligamentum teres uteri) is a narrow flat band attached to the uterus just in front of and a little below the opening of the Fallopian tube. Near the uterus it contains numerous smooth muscle fibres, which are continuous with those of the uterus; further on it is chiefly composed of fibrous connective tissue. Lying in the anterior part of the broad ligament, it reaches the pelvic wall, and is then directed forwards and slightly upwards to cross the obliterated hypogastric artery and the pelvic brim. After it has reached the

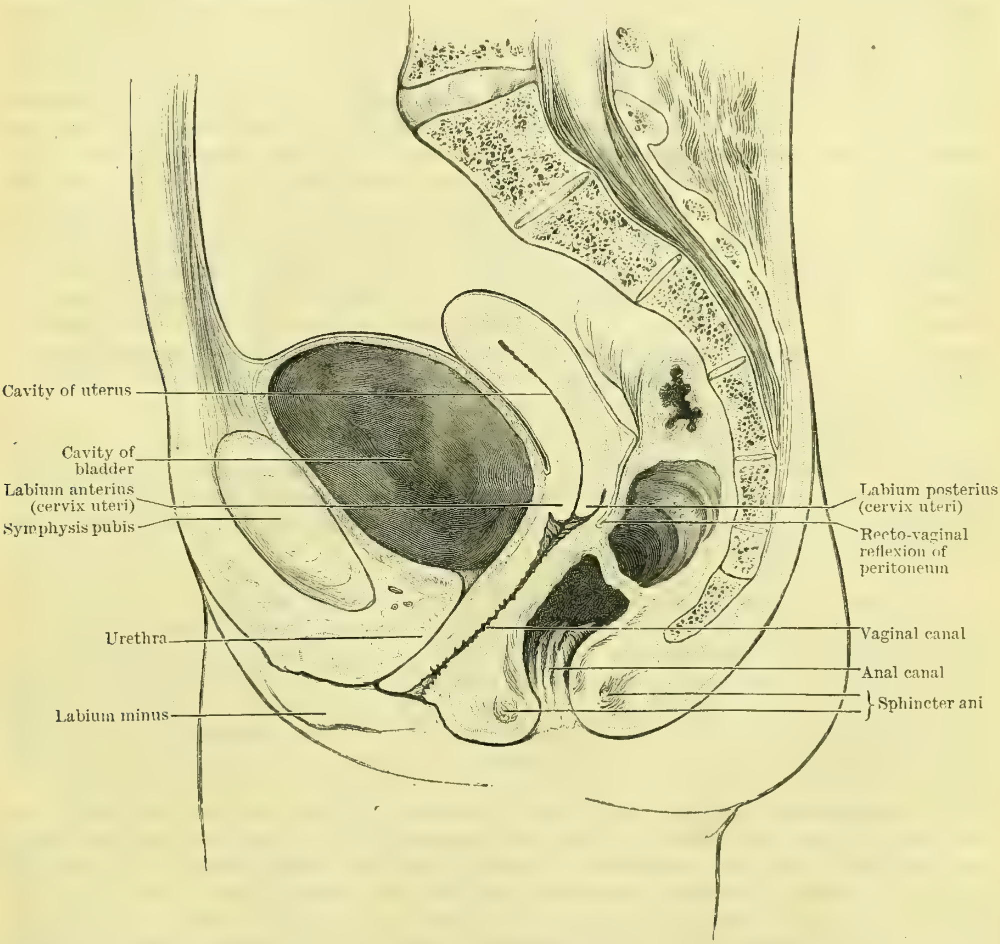


Fig. 775.—Mesial Section of the Pelvis in an Adult Female.

The cavity of the uterus is indicated diagrammatically. From a specimen in the Anatomical Department, Trinity College, Dublin.

pelvic wall its course is comparable to that of the vas deferens in the male (Fig. 773), and, like the latter, it leaves the abdomen to traverse the inguinal canal. It finally ends in the subcutaneous tissue and skin of the labium majus. Its terminal part is composed of connective tissue only.

In some cases a small diverticulum of the peritoneal cavity can be traced accompanying the round ligament through the abdominal wall. This is called the **canal of Nuck** (processus vaginalis peritonæi), and corresponds to the processus vaginalis of the male (p. 1111).

The round ligament of the uterus represents the lower portion of the gubernaculum testis which appears in the male embryo (see p. 1112).

Position and Relations of the Uterus.—The position occupied by the uterus in the pelvis is not always the same, as it varies to some extent with the conditions of the neighbouring organs. The lower cervical part is, however, much more firmly fixed in place than the body and fundus, which possess a considerable amount of mobility. The uterus rarely lies exactly in the mesial plane of the body, but usually bends to one or other side, most frequently towards the right. The anterior surface of the uterus rests against the bladder, and follows the rising or falling of its superior wall as that organ becomes filled or emptied. When the bladder is empty the long axis of the uterus points forwards and upwards, and the organ is said to be in an *anteverted* position. Also the long axis of the uterus is bent on itself where the body joins the cervix, and so the organ is said to be *anteflexed.* The anteflexion is due to the fact that the more rigid cervix is firmly fixed, while the movable upper part of the uterus sinks forwards, following the bladder wall. With the empty condition of the bladder the angle formed between the long axis of the uterus and that of the vagina is about a right angle. When the bladder becomes filled, the antevertion and anteflexion of the uterus become less marked, owing to the body and fundus being pushed backwards. Finally, if the rectum be empty and the bladder very much distended, the uterus is pushed so much backwards that the long axis of the organ may nearly correspond to that of the vagina. The uterus is then said to be *retroverted.* In the upper part the peritoneum intervenes between the anterior surface of the uterus and the bladder, on which it lies; lower down the two organs are separated merely by connective tissue. The posterior surface looks into the pouch of Douglas, and is usually, like the fundus above, in relation to some loops of intestine. Laterally the uterus is related to the broad ligaments. The terminal parts of the ureters pass downwards, inwards, and a little forwards on each side of the cervix, but are separated from it by an interval of about three-quarters of an inch. The lowest part of the cervix is, as we have seen, enclosed within the cavity of the vagina.

On each side of the cervix uteri and upper part of the vagina there is an interval in which lie numerous large vessels. These are surrounded by loose fatty tissue, which is continued upwards for a considerable distance between the layers of the broad ligament. This loose tissue, which is of surgical importance, has received the name **parametrium**.

Structure of the Uterus.—The thick uterine wall is composed of three chief layers, which are termed respectively the serous, the muscular, and the mucous coats.

The **serous coat** or **perimetrium** (tunica serosa), is derived from the peritoneum, and covers the whole organ except the anterior surface of the cervix, and the part of the cervix which projects into the vagina. At the lateral borders it is continued into the broad ligaments. The serous coat of the uterus is very firmly adherent to the deeper layers, and cannot be easily peeled off without tearing either it or the underlying muscular tissue.

The **muscular coat** (tunica muscularis) is composed of unstriped fibres, and forms the chief part of the uterine wall. The more superficial layer of this muscular coat sends prolongations into the recto-uterine folds, into the round and broad ligaments of the uterus, and into the ovarian ligaments. Other fibres join the walls of the Fallopian tubes. The main branches of the blood-vessels and nerves of the uterus lie among the muscle fibres. In the deeper layers of the muscular coat a considerable amount of connective tissue and some elastic fibres are to be found. The muscular coat of the cervix (tunica muscularis cervicis) contains more connective and elastic tissue than that of the body, and hence the greater firmness and rigidity of the cervical part of the uterus.

The deeper and thicker part of the muscular tissue of the uterus is considered by some anatomists to represent a **muscularis mucosæ**, and is therefore described as part of the mucous coat. The deep and superficial portions of the muscular coat are, however, quite continuous, and there is no representative of a submucous vascular layer of tissue such as in the alimentary canal separates the muscular coat from the muscularis mucosæ. In the uterus the blood-vessels lie in the muscular coat.

The **mucous coat** (tunica mucosa) in the body of the uterus is smooth and soft, and covered by columnar ciliated epithelium. Simple tubular glands (glandulæ uterinæ), also lined by a ciliated epithelium, are present in the mucous membrane, and penetrate in their deeper parts into the muscular coat. In the cervix of the uterus the mucous

coat is firmer and more fibrous than in the body, and its surface is not smooth, but presents a number of peculiarly disposed ridges, which have been already described. Like the mucous membrane of the body of the uterus, that of the cervix is covered by a ciliated epithelium which passes into squamous epithelium just inside the external os uteri. The cervix uteri possesses, in addition to unbranched tubular glands, resembling those present in the body, numerous somewhat branched glands (glandulæ cervicales uteri). Both kinds of glands are lined by ciliated epithelium. In many cases little clear retention cysts, **ovules of Naboth**, are to be seen in the cervical mucous membrane, which arise as a result of obstruction at the mouths of the glands.

Difference in the Uterus at Different Ages.—At birth the cervix uteri is relatively larger than in the adult organ, and its cavity is not distinctly marked off from the interior of the body by an internal os uteri. At this time also the arbor vitæ extends throughout the whole length of the uterus. The organ grows slowly until just before puberty, when its growth is rapid for a time. As the body increases in size the mucous membrane becomes smooth and the arbor vitæ becomes restricted to the cervix. In women who have borne children the cavity remains permanently somewhat wider and larger than in cases where the uterus has never been pregnant.

In old age the uterine wall becomes harder and has a paler colour than it possesses in the young subject.

Variations.—In rare cases the uterus may be divided by a septum into two distinct cavities, or its lateral angles may be produced into straight or curved processes, called "horns" or cornua. The latter abnormality recalls the appearance of the bicornuate uteri of some animals. Both the above conditions arise from an arrest in the fusion of the two separate tubes—the Müllerian ducts—which normally unite to form the uterus.

Periodic Changes in the Uterine Wall.—At each menstrual period a remarkable series of changes occurs which results in the periodic shedding of the superficial parts of the uterine mucous membrane. For a few days before menstruation begins, the mucous membrane gradually thickens and becomes more vascular, while at the same time its surface becomes uneven. Soon the superficial parts of the mucous membrane disintegrate and hæmorrhage takes place from the small superficial blood-vessels. In this way a hæmorrhagic discharge is caused, and the superficial parts of the uterine mucous membrane are shed at each period. When menstruation is over the mucous membrane is rapidly regenerated.

Pregnant Uterus.—The pregnant uterus increases rapidly in size and weight, so that from being three inches in length and one ounce in weight, it becomes by the eighth month about seven or eight inches in length and sometimes as much as two pounds in weight. In shape the uterus is now oval or rounded, with a thick wall composed chiefly of muscle fibres arranged in distinct layers. The rounded fundus is very prominent. The round ligaments are stronger and better marked, and the layers of the broad ligament become separated in their inner parts by the growth of the uterus between them. The blood-vessels, especially the arteries, are very large and tortuous. The changes which occur in the mucous membrane of the pregnant uterus are intimately connected with the manner in which the developing fœtus receives its nutrition, and have been noticed on p. 51.

Vessels and Nerves of the Uterus.—The uterus receives its arterial supply from the **uterine arteries**, which are branches of the internal iliac arteries, and also from the **ovarian arteries**, branches of the aorta. The vessels derived from these two sources communicate freely with one another. Each uterine artery, reaching the side of the lower part of the uterus, divides into a large branch which passes upwards to supply the body and fundus, and a much smaller branch which passes downwards to supply the cervix. The vessels distributed to the body and fundus have an exceedingly tortuous course. The branches of the uterine artery, having entered the muscular coat, break up within its deeper layers into smaller twigs which supply the muscular tissue and the mucous coat. The small uterine branch from the ovarian artery reaches the uterus in the region of the lateral angle. During pregnancy the arteries become enormously enlarged.

The thin walled **veins** form a plexus which pours its blood into the tributaries of the internal iliac vein.

The **nerves** of the uterus are derived chiefly from a plexus placed in the neighbourhood of the cervix uteri, to which the term **cervical ganglion** or **plexus utero-vaginalis** is applied. Superiorly this plexus is continuous with the hypogastric plexus, but it also receives fibres from

the third and fourth sacral nerves. In addition to fibres from the plexus utero-vaginalis, the uterus receives fibres directly from the **hypogastric plexus**, and also from the **vesical plexus.**

The numerous **lymphatic vessels** coming from the body of the uterus end for the most part in the lumbar lymphatic glands. Along the course of the round ligament of the uterus there are a few lymphatic vessels which establish a connexion between the lymphatic network surrounding the uterus and the inguinal lymphatic glands. The lymphatics from the cervix uteri end in the glands placed near the bifurcation of the common iliac artery.

THE VAGINA.

The **vagina** is a passage about three inches in length, open at its lower end, and communicating above with the cavity of the uterus. The passage is directed downwards and forwards, describing a slight curve which is convex backwards. The axis of the vagina forms with that of the uterus an angle which is open

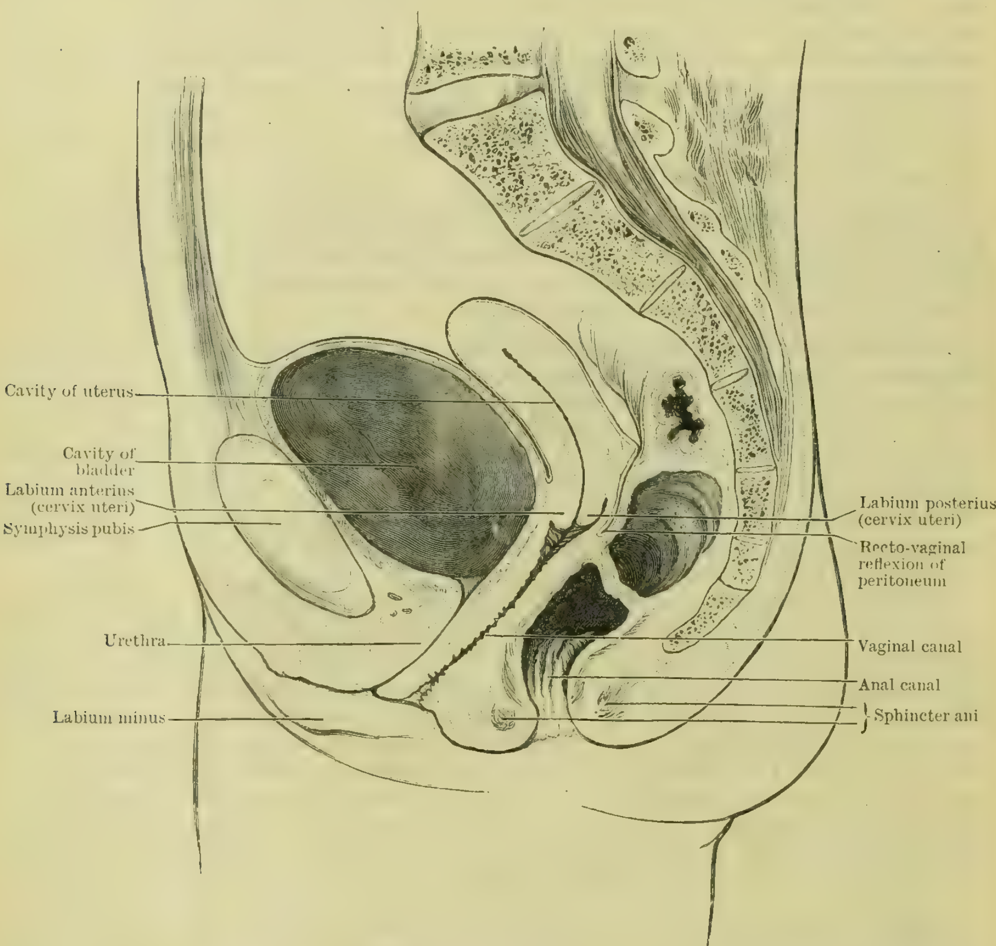


Fig. 776.—Mesial Section of the Pelvis in an Adult Female.

The cavity of the uterus is indicated diagrammatically. From a specimen in the Anatomical Department, Trinity College, Dublin.

forwards. This angle is usually somewhat greater than a right angle, but varies with the condition of the neighbouring viscera (p. 1132). The vagina is wider in its middle part than it is at either end, and normally its anterior and posterior walls are in contact. In transverse section the lower part is usually an H-shaped cleft, the middle part a simple transverse slit, while the lumen of the upper portion, into which the cervix uteri projects, is more open. The lower part of the cervix has the appearance of entering the vagina through the upper portion of its anterior wall (Fig. 776). As more of the posterior than of the anterior part of the cervix

projects into the vagina, a deeper recess is formed between the vaginal wall and the cervix behind, than in front or laterally. The term **anterior fornix** is often applied to the angle or recess in front of the cervix uteri, and **posterior fornix** to the deeper angle formed behind the cervix. The *anterior* vaginal wall (paries anterior) is shorter than the *posterior* (paries posterior), the former being about three inches in length, the latter about three and a half inches. At its lower end the vagina opens into the urogenital cleft, the opening being situated behind the orifice of the urethra and the clitoris, and between the labia minora. The opening is partly closed in the virgin by a thin crescentic or annular fold called

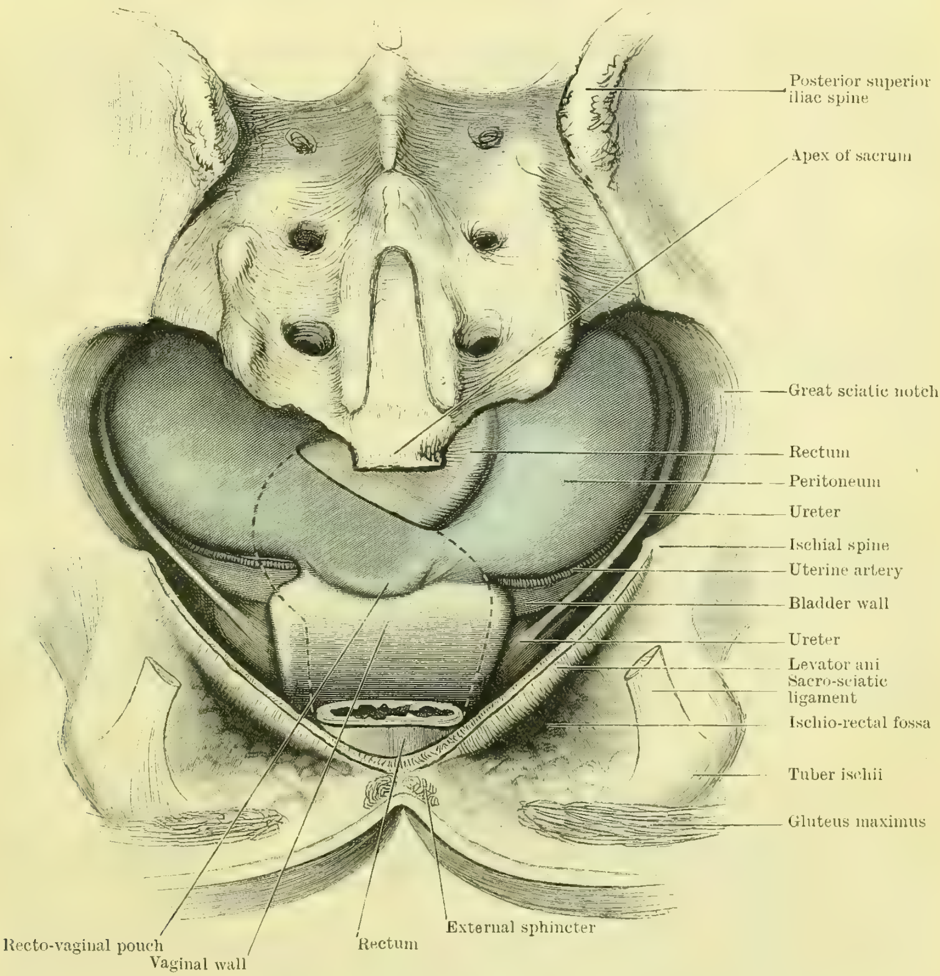


FIG. 777.—THE VAGINA, BASE OF BLADDER, AND RECTO-VAGINAL POUCH OF PERITONEUM, seen from behind.

The coccyx and sacro-sciatic ligaments, together with the muscles attached to them, have been removed. The levatores ani have been separated along the median raphe, and drawn outwards. A considerable portion of the rectum has been removed, but the position which it occupied is indicated by the dotted lines. The peritoneum is indicated by a blue colour. The recto-vaginal pouch is probably not quite so deep as usual.

the **hymen**, torn fragments of which persist round the opening, as the **carunculæ hymenales**, after the fold itself has been ruptured.

Relations of the Vagina.—The anterior wall of the vagina in its upper part lies against the base of the bladder, but is separated from it by loose connective tissue. Lower down, the anterior wall in the mesial line is intimately connected with the urethra (Fig. 776). Near the middle line the posterior wall, in its upper portion, is covered for a distance of about a quarter of an inch by the peritoneum, which here forms the anterior boundary of the deepest part of the pouch of

Douglas. Lower down, the posterior wall lies close against the rectum, from which it is separated by a layer of the pelvic fascia. As, however, the orifice of the vagina is approached, the rectum and vagina become separated by a considerable interval, which is occupied by a mass of fibrous and fatty tissue, often called the "perineum" or "perineal body." At the sides the vagina is supported by the levatores ani muscles. The terminal part of the ureter lies not far from the side wall of the upper part of the vagina, as it passes from above and behind downwards, inwards, and a little forwards to reach the bladder. Near its termination the vagina pierces the triangular ligament, and is related laterally to the bulbus vestibuli, the gland of Bartholin, and the sphincter vaginæ muscle.

Structure of the Vagina.—The vaginal wall has a distinct **muscular coat** (tunica muscularis), composed of unstriped muscle fibres, most of which are longitudinally disposed. Towards the lower end of the passage circularly-disposed striped muscle fibres are found in the deeper part of the muscular coat. The thick **mucous membrane** (tunica mucosa), which has a stratified scaly epithelium, is corrugated, and presents a number of transverse ridges or elevations called **rugæ vaginales**. In addition to these transverse rugæ, a slightly marked longitudinal ridge, or column, is to be seen on the anterior and on the posterior wall of the vagina. These receive the name **columnæ rugarum**, and, like the transverse rugæ, are best seen in young subjects, and in the lower part of the vagina. The urethral canal lies in close relationship to the anterior column of the vagina in its lower part, and hence this portion of the anterior column is sometimes called the **carina urethralis** (Figs. 746, B and 776).

Within the mucous coat are to be found small collections, or nodules, of lymphoid tissue.

The vaginal wall is surrounded by a layer of loose vascular connective tissue containing numerous large communicating veins.

Variation.—In rare cases the vagina has been found divided by an incomplete septum into two passages. Such abnormality is due to an incomplete fusion of the lower portions of the Müllerian ducts from which the vagina is developed in the embryo.

Vessels and Nerves of the Vagina.—The blood supply of the vagina is for the most part derived from branches of the **vesico-vaginal artery**, the vaginal branch of the **uterine artery**, the vaginal branches of the **middle hæmorrhoidal artery**, and from the branches of the **internal pudic.** The **veins** form a plexus surrounding the vaginal wall, and drain their blood into the tributaries of the internal iliac. The **lymphatics** from the upper part of the vagina join the internal iliac group of glands, while those from the lower part end in the superficial inguinal glands. The **nerves** of the vagina are derived from the **plexus utero-vaginalis**, and from the **plexus vesicalis.** Other fibres are derived directly from the **third** and **fourth sacral nerves.**

THE FEMALE EXTERNAL GENITAL ORGANS.

The term **vulva**, or **pudendum** (pudendum muliebere), is often applied collectively to the female external genital organs, *i.e.* to the libia majora and the structures which lie between them.

Labia Majora.—The labia majora represent the scrotum in the male, and form the largest part of the female external genital organs. They form the lateral boundaries of the **urogenital cleft** (rima pudendi), into which the urethra and vagina open. Each labium is a prominent rounded fold of skin, narrow behind where it approaches the anus, but increasing in size as it passes forwards and upwards to end in a median elevation, the **mons pubis or Veneris.** The mons Veneris, also called the **anterior commissure** (commissura labiorum anterior), lies over the symphysis pubis, and, like the labia majora, it is composed chiefly of fatty and areolar tissue, and is covered by hair. The outer convex surface of each labium majus is covered by skin resembling that of the scrotum in the male, but the inner flatter surface is smooth, and presents a more delicate integumentary covering. In some cases the posterior narrow ends of the labia majora are connected across the middle line in front of the anus by a slight transverse fold—the **posterior commissure** (commissura labiorum posterior).

Usually, especially in young subjects, the labia majora are the only visible parts of the external genital organs, since they are in contact with one another, and completely enclose the structures within the urogenital cleft.

The round ligament of the uterus ends in the fatty tissue of the labium majus. The superficial subcutaneous tissue resembles that of the scrotum, but contains no muscular fibres. The nerve supply corresponds with that of the scrotum, the anterior part of each labium being supplied by the branches of the **ilio-inguinal nerve**, and the posterior part by branches from the **internal pudic**, and by the perineal branch of the small sciatic nerve. The blood-vessels of the labia majora are derived from the **superficial pudic arteries** and from the perineal branches of the **internal pudic vessels**.

Labia Minora.—The labia minora, or nymphæ (labia minora pudendi), are a pair of much smaller and narrower longitudinal folds, usually completely enclosed within the cleft between the labia majora. Diminishing in size, and becoming less marked in their posterior parts, the labia minora end by gradually joining the inner surfaces of the labia majora. In the young subject, a slightly raised transverse fold is usually seen connecting the posterior ends of the labia minora; to this fold the term **frenulum** (frenulum labiorum pudendi), or **fourchette**, is applied. Traced forwards, each labium minus divides into two portions, an outer and an inner. The outer portions of the two labia unite over the glans clitoridis, and form a fold or covering for it, called the **præputium clitoridis**. The inner portions, uniting at an acute angle, join the glans and form the **frenulum clitoridis**. The skin of the labia minora resembles the integument on the inner or deep surface of the labia majora, being smooth, moist and pink in colour. The inner surfaces of the labia minora are in contact with one another; their outer surfaces are applied against the inner aspects of the labia majora.

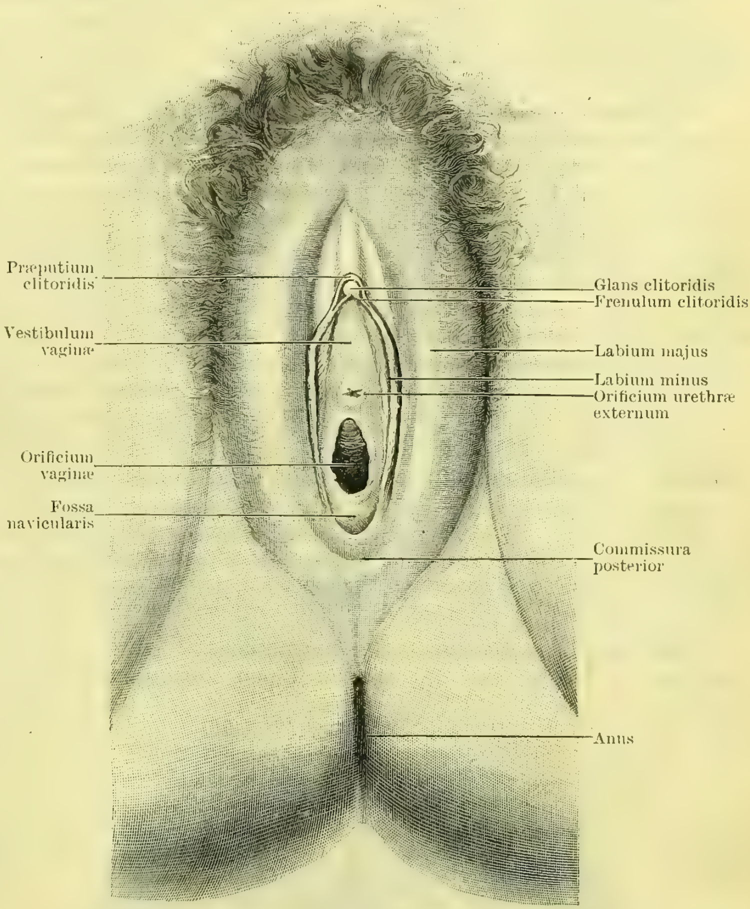


Fig. 778.—Female External Genital Organs.

The hymen has been ruptured, but the fourchette is seen stretching across behind the fossa navicularis and in front of the posterior commissure. The ducts of Bartholin's glands open in the intervals between the vaginal orifice and the labia minora.

The openings of the urethra and vagina are placed in the middle line, in the interval between the labia minora, which must be separated to bring them into view.

The **vestibule** (vestibulum vaginæ) is the name applied to the cleft that lies between the labia minora and behind the glans clitoridis. In its floor are the openings of the urethra, the vagina and the minute ducts of Bartholin's glands.

The **fossa navicularis** is the part of the vestibule placed behind the vaginal opening and in front of the fourchette.

The **external urethral orifice** lies immediately in front of that of the vagina, and is about one inch behind the glans clitoridis. The opening has the appearance of a vertical slit, or of an inverted V-shaped cleft, the slightly prominent margins of which are in contact.

The **vaginal opening** (orificium vaginæ) lies further back and below the orifice of the urethra. The appearance of the opening varies with the condition of the **hymen**—a membrane which in the young subject partly closes the aperture. When the hymen is intact the opening is small, and is only seen when the membrane is put on the stretch. When the hymen has been ruptured the opening is much larger, and round its margins are often seen small projections—**carunculæ hymenales**—which are to be looked upon as persistent portions of the hymen.

The **hymen** is a thin membranous fold, partially closing the lower end of the vagina, and usually perforated somewhat in front of its middle point. The position of the opening gives the fold, when stretched, a crescentic appearance. The opening in the hymen is sometimes cleanly cut, sometimes fringed. The membrane is not stretched tightly across the lower end of the vagina, but is so ample that it projects downwards into the urogenital fissure, and the parts of its upper surface are in contact with one another on each side of the opening. The opening is thus a mesial slit whose margins are normally in contact. The upper surface of the hymen is directly continuous with the vaginal wall, and on it are to be seen slight ridges continuous with the vaginal rugæ.

Developmentally the hymen appears to be a portion of the vagina.

On each side of the vaginal opening, and close against the attached margin of the labium minus, is the minute aperture of the duct of Bartholin's gland. This is usually just large enough to be visible to the unaided eye.

Numerous minute mucous glands (glandulæ vestibuli minores) open on the surface of the mucous membrane of the vestibule, between the urethral and vaginal orifices. The opening of the ductus para-urethralis at the side of the urethral orifice has been already noted (p. 1103).

Sebaceous glands are present on the labia majora and minora, and beneath the præputium clitoridis. In the latter situation the secretion of these helps to form the smegma clitoridis.

Clitoris.—The clitoris is the morphological equivalent of the penis, and is composed of a body and two crura. Upon the summit of the body is a minute glans. Unlike the penis, the clitoris is not traversed by the urethra.

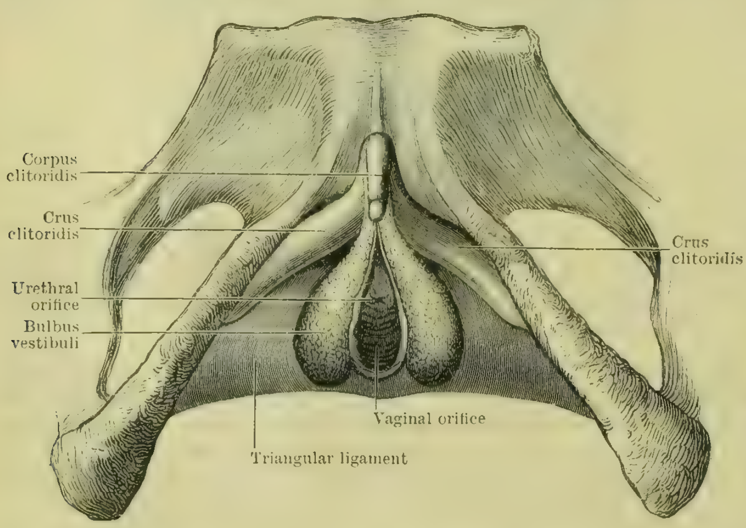


FIG. 779.—DISSECTION OF THE FEMALE EXTERNAL GENITAL ORGANS.
Drawn from a specimen in the Anatomical Department, Trinity College, Dublin.
The suspensory ligament is seen passing upwards towards the symphysis pubis.

The **body of the clitoris** (corpus clitoridis) is composed for the most part of erectile tissue resembling that of the penis in the male. It is about an inch or an inch and a half in length, and is bent upon itself, forming an angle open downwards. The body of the clitoris tapers towards its distal end, which is covered by the glans clitoridis. The organ is enclosed in a dense fibrous coat, and is divided by an incomplete **septum** (septum corporum cavernosorum) into two symmetrical and some-

what cylindrical portions, the **corpora cavernosa clitoridis.** These represent the corpora cavernosa of the male, and diverge from one another at the root of the clitoris to form the crura clitoridis. A **suspensory ligament** (ligamentum suspensorium clitoridis) passes from the fibrous coat of the body of the clitoris to the symphysis pubis.

The **glans clitoridis** is a small mass of erectile tissue which is fitted over the pointed end of the body. It possesses, like the glans penis which it represents, a very sensitive epithelium. The **prepuce**, or fold of skin which covers it, and the **frenulum** which is attached to it inferiorly, are continuous with the labia minora (Fig. 778).

The **crura clitoridis** diverge from the body posteriorly, and are attached to the sides of the pubic arch. Each is continuous with one of the corpora cavernosa, and has a firm fibrous sheath, which is covered by the corresponding ischio-cavernosus or erector clitoridis muscle. In structure the crura and body of the clitoris resemble the corpora cavernosa penis, while the glans more closely resembles the bulbus vestibuli, with which it is continuous through a structure known as the pars intermedia.

In the seal and some other animals, a bone, which represents the os penis of the male, is developed in the septum of the clitoris. This bone receives the name **os clitoridis.**

Arteries and Nerves of the Clitoris.—Each crus receives a branch (artéria profunda clitoridis) from the **internal pudic artery,** while the glans is supplied by branches of the **dorsal arteries** of the clitoris (arteriæ dorsalis clitoridis). The nerve supply of the clitoris is derived partly from the **hypogastric sympathetic plexus** and partly from the **dorsal nerves** of the clitoris.

Bulbus Vestibuli.—The bulbus vestibuli is a mass of erectile tissue, in the female, which corresponds developmentally to the corpus spongiosum urethræ of the male. In the female the fusion of the two halves of this structure is not nearly so complete as in the male, for the vagina and urethra separate the bulbus vestibuli into two lateral portions which are only slightly connected in front by a narrow median part called the **pars intermedia.** Each lateral portion of the bulb is thick and massive posteriorly, and more pointed in front where it joins the pars intermedia. It rests against the side wall of the vagina, and upon the superficial aspect of the triangular ligament. Superficially it is covered by the bulbo-cavernosus muscle. The pars intermedia lies above the urethra, and becomes continuous with the tissue of the glans clitoridis. It represents a part of the corpus spongiosum urethræ of the male.

The bulbus vestibuli is for the most part composed of minute convoluted blood-vessels, held together by a very small amount of connective tissue. These vessels frequently anastomose with one another, and those of each lateral half are continuous with the vessels of the pars intermedia and of the glans clitoridis.

The blood supply of the bulb is derived on each side from a branch (arteria bulbi vestibuli) of the internal pudic.

The Glands of Bartholin.

The **glands of Bartholin** (glandulæ vestibulares majores) are placed one on each side of the lower part of the vagina, and represent Cowper's glands in the male. They are often overlapped by the posterior ends of the bulbus vestibuli, and are covered by the bulbo-cavernosus muscle. Each is about the size and shape of a small bean, and possesses a long slender duct which opens into the urogenital cleft in the angle between the attached border of the labium minus and the vaginal opening.

DEVELOPMENT OF THE UROGENITAL ORGANS.

In tracing the developmental history of the urogenital system we may begin with an embryo of fifteen days old. About this time a duct, which runs in the longitudinal direction, and occupies a position on the outer side of the paraxial mesoblast, begins to develop on each side of the body. With the exception of the anterior portion of the cloaca and the proximal part of the allantois, this duct, which has received the name of **Wolffian duct,** is the earliest formed structure from which, or in connexion with which, any portion of the adult urogenital system is derived.

The Wolffian duct serves as the canal or duct for the primitive secretory organ of the embryo. It does not persist as such in the adult, yet the adult of both sexes retains structures which have their origin in the Wolffian duct. These adult structures may be in a rudimentary or in a functional condition, and the functions performed by them may have changed during the course of development. In the male the **canal of the epididymis,** the **vas deferens,** and the **common ejaculatory duct,** are to be looked upon as directly developed from the Wolffian duct of the embryo; while in the female the **longitudinal duct of the parovarium** and the **hydatids of Morgagni** are rudimentary structures having a like origin. Further, the **ureter** and its **pelvis,** together with the complicated system of

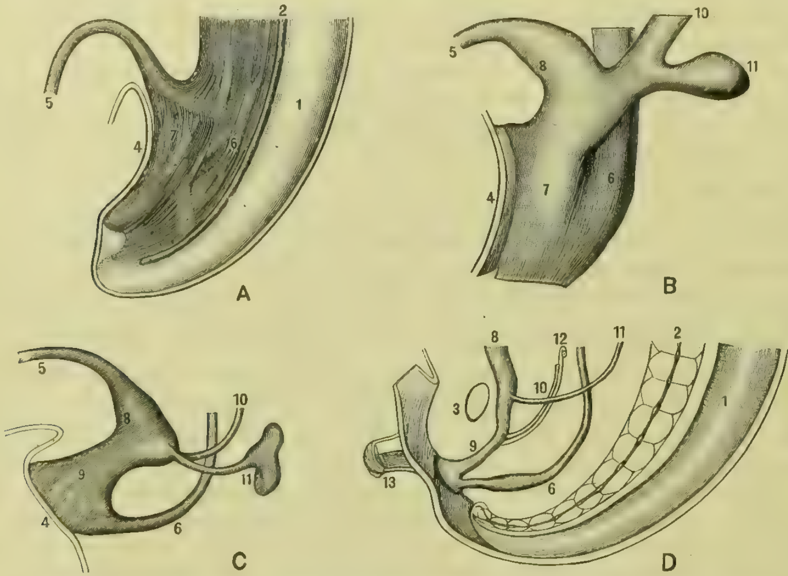


FIG. 780.—DEVELOPMENT OF THE BLADDER, URETER, AND KIDNEY. From the models by Professor Keibel.

A. Caudal portion of an embryo of 15 to 18 days old. The cloaca is relatively very large, and is not yet joined by the Wolffian ducts; an indication is present of the separation of the cloaca into dorsal or rectal, and ventral or urogenital, subdivisions.

B. The cloaca of an older embryo—25 to 27 days old. The subdivision of the cloaca is more clearly marked. The Wolffian duct is seen joining the anterior subdivision, and from the lower part of the duct an outgrowth is present, which gives origin to the ureter and the kidney.

C. Still older stage (36 to 37 days old). The ureter has acquired a separate opening into the developing bladder, which is placed upon the same level as that of the Wolffian duct. The kidney is much more advanced, and the rectum is becoming separated from the urogenital canal.

D. Female embryo $8\frac{1}{2}$ to 9 weeks old. The openings of the ureter and genital ducts have become separated by a considerable interval. The urogenital canal and rectum have acquired separate openings.

1, Spinal cord; 2, Notochord; 3, Pubic symphysis; 4, Cloacal membrane, forming the floor of the ectodermal cloacal fossa; 5, Allantoic canal; 6, Rectum, or rectal subdivision of cloaca; 7, Urogenital subdivision of cloaca; 8, Bladder; 9, Urogenital canal; 10, Wolffian duct; 11, Ureter (or ureter and developing kidney); 12, Müllerian duct; 13, Genital eminence.

kidney tubules which open into it, arise in both sexes as an outgrowth from the Wolffian duct. In the male the **vesicula seminalis** also arises as a diverticulum of the Wolffian duct (Fig. 781).

The primitive excretory organ—**mesonephros**—develops in connexion with the anterior part of the Wolffian duct (p. 30), and is during the early life of the embryo a most important structure. With the development of the permanent kidney the mesonephros atrophies, yet some of its tubules persist in the adult. The **vasa efferentia,** the **ductuli aberrantes,** and the rudimentary **paradidymis** (organ of Giraldès) in the male, and the rudimentary tubules of the **parovarium** (epoophoron) and of the **paroophoron** in the female, are structures which owe their origin to tubules of the mesonephros.

Soon after the formation of the Wolffian ducts two other longitudinally-disposed canals, called the **Müllerian ducts,** are developed. These open at their cephalic ends into the body cavity, and at their caudal ends, unlike the Wolffian ducts, they unite with one another in the middle line. From them are formed in the female—the **Fallopian tubes,** the **uterus,** and the **vagina**; and in the male—the **hydatids** of the testis or of the epididymis and the **utriculus prostaticus.**

The Wolffian and Müllerian ducts open at their caudal ends into the ventral or

urogenital part of the **cloaca**, which in the course of development becomes transformed into the **bladder** and the **urogenital canal** of the embryo (Figs. 780 and 781). The developing ureter at first opens as a diverticulum from the Wolffian duct, at a short distance from the point where the latter joins the cloaca. Soon, however, the ureters acquire independent openings into the cloaca, which become gradually shifted further from one another and from those of the Wolffian ducts. The ureters are now found to open into the anterior portion of the cloaca which lies nearer to the head of the embryo than the part with which the Wolffian ducts are connected. This cephalic portion receiving the ureters becomes, in the male, the bladder and the upper part of the prostatic urethra; in the female, the bladder and the entire urethra (Fig. 782). The caudal part, lying below the level of the entrance of the Wolffian ducts, is the urogenital canal, and is represented in the adult male by the lower part of the prostatic and the membranous urethra; in the female by the part of the urogenital fissure which immediately surrounds the openings of the urethra and vagina (Fig. 782). The united Müllerian ducts open into the lower part of the cloaca or urogenital canal, between the Wolffian ducts of opposite sides. In the male the position of this opening, which is represented in the adult by the opening of the uterus masculinus, remains almost unchanged; in the female, on the other hand, the urogenital canal becomes so much shortened during development, that the opening, which in this sex is represented by the orifice of the vagina, comes to the surface at the bottom of the urogenital fissure (Fig. 782). The cavity of the developing bladder is directly continuous above with that of the allantois, and by some authorities the bladder is described as arising as a dilatation of the proximal part of the allantois.

When the ectodermal **cloacal fossa** is formed, after the complete separation of the cloaca into anterior or urogenital, and posterior or rectal parts, it communicates with the rectum behind and with the urogenital canal in front (p. 43). The fossa is bounded laterally by a well-marked skin fold, and at its anterior end is situated the **sexual eminence.** This eminence becomes the terminal portion of the **penis** or of the **clitoris**, and its posterior surface is grooved longitudinally in such a manner that the proximal end of the groove lies near the opening of the urogenital canal into the cloacal fossa.

In the male the lips of this groove on the sexual eminence, meeting together, form a canal which, in the adult, traverses the glans penis as the terminal part of the urethra. The lateral margins of the cloacal fossa, behind the sexual eminence, meet together, and fusing in the middle line, convert the fossa into a canal, which becomes the spongy portion of the adult urethra. In this way all the cloacal fossa lying in front of the rectum becomes closed over to form the third part of the urethra. The last portion of the fossa to disappear from the surface is the anterior part, which lies just at the base of the sexual eminence (Fig. 782). The spongy part of the urethra is thus derived from the *ectodermal cloacal fossa*, while the prostatic and membranous parts owe their origin to the *endodermal cloaca.*

In the female the margins of the cloacal fossa remain separate throughout life, and the fossa persists as the **urogenital space.** The groove on the sexual eminence, or glans clitoridis, closes over, but does not form a canal as in the male. The urogenital canal, at first like that of the male, becomes shorter and shorter during development. Owing to this shortening the lower end of the fused portions of the Müllerian ducts, which opens into the canal, and from which the **vagina** is formed, appears in the adult to open directly into the fossa (urogenital space) behind the channel leading from the bladder. From the latter channel is formed the female urethra (Fig. 782).

Wolffian Duct and Embryonic Secretory Organ.—The **Wolffian duct** arises in the mesoblast, about the fifteenth day, as a solid cord of cells occupying a position immediately to the outer side of the mesoblastic somites and to the inner side of the body cavity. When first recognised the duct lies immediately beneath the epiblast, and as it grows backwards to reach the cloaca it is often found to be intimately connected with the epiblast. This close connexion of the duct with the epiblast, in the early stages, is by some authorities supposed to indicate a primitive ectodermal origin of the canal, but by others, and apparently with more reason, to be a trace of the opening of the ducts on the surface of the body, such as exists in connexion with the excretory organs of lower animals. During the third week the cellular cord which represents the Wolffian duct acquires a lumen, and about the end of the same week the duct in its growth reaches the cloaca. As soon as the cloaca has become divided into dorsal and ventral subdivisions, the Wolffian duct is seen to end in the caudal part of the ventral subdivision, which becomes the urogenital canal (Fig. 781).

The **Wolffian body** or **mesonephros** is developed in the mesoblast of the "intermediate cell mass," immediately to the outer side of the Wolffian duct, and consists of a number

of transversely-arranged canals or tubules, each of which opens at its inner end into the Wolffian duct, while its outer extremity ends blindly. These transverse tubules, like the canal into which they open, are at first solid cellular structures, and only later acquire a distinct lumen. Increasing rapidly in size and number, the tubules become twisted and tortuous, and the free outer end of each dilates to form a capsule invaginated upon itself and containing a bunch of capillary blood-vessels similar to the glomeruli of the adult kidney. The number of transverse tubules does not correspond to the number of somites, but several tubules are present for each somite in which a portion of the Wolffian body occurs. The Wolffian body is developed throughout the greater part of the length of the embryo, and reaches from the fifth somite in front to the fifth lumbar somite behind. The anterior part, which possibly represents the "**pronephros**" of lower vertebrates, very rapidly atrophies. When at its greatest development (about the eighth week) the mesonephros forms a relatively large glandular mass projecting into the dorsal part of the body cavity, and extending from the region of the liver to the caudal end of the body cavity.

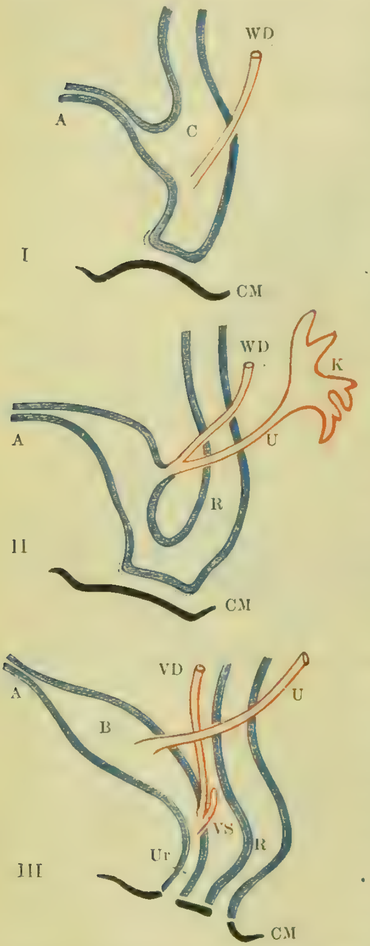


FIG. 781.—DIAGRAM TO ILLUSTRATE THE MANNER IN WHICH THE URETER, THE VAS DEFERENS, AND THE BLADDER ARISE IN THE EMBRYO.

The structures developed from the cloaca are indicated in blue, those from the Wolffian duct in red, and the ectoderm in black.

The manner in which the rectum and bladder become separated and acquire openings into the ectodermal cloacal fossa is shown in II. and III. (A. H. Young and A. Robinson).

A.	Allantois.	R.	Rectum.
B.	Bladder.	Ur.	Urogenital canal.
C.	Cloaca.	U.	Ureter.
CM.	Ectoderm of cloacal fossa.	VD.	Vas deferens.
		VS.	Seminal vesicle.
K.	Pelvis of kidney.	WD.	Wolffian duct.

In the lower vertebrates the tubules of the Wolffian body open into the body cavity by wide ciliated mouths, and in these animals the tubules are developed as outgrowths of the peritoneal membrane. In anamniate vertebrates the mesonephros persists as the secretory organ of the adult.

As the permanent kidney is developed the mesonephros atrophies; a portion of it, however, is retained *in the male*, and forms the excretory apparatus of the testis. The Wolffian duct becomes the canal of the epididymis and the vas deferens of the adult (see p. 1145). *In the female*, when the permanent kidney is formed, the mesonephros and its duct undergo atrophy to a greater extent than in the male, and are only represented in the adult by rudimentary structures (see p. 1145).

Ureter and Permanent Kidney.—The kidney and ureter arise as a tubular diverticulum from the Wolffian duct close to the point where the latter joins the cloaca. This diverticulum is seen first during the fourth week, and grows from behind forwards, dorsal to the body cavity. Even in its very early condition the portion of the outgrowth which lies nearest to the Wolffian duct, and from which the adult ureter is developed, is more slender than the distal part, which becomes branched, and grows out to form the pelvis and calyces of the ureter. The uriniferous tubules of the kidney arise as branching tubular outgrowths from the calyces into the surrounding mesoblast. The blind distal end of each tubule soon dilates to form a capsule which, becoming invaginated on itself, encloses a tuft of capillary blood-vessels. The Malpighian corpuscles arising in this manner are found in the human kidney as early as the eighth week.

According to some embryologists it is only the collecting tubules that are formed in this manner, and the other tubules of the kidney have a mesoblastic origin independent of the outgrowth which gives origin to the ureter and its pelvis. These authorities state that the kidney tubules arise in the mesoblast, and only later acquire a connexion with the outgrowths from the ureter. Recent observation, however, does not support these statements.

The kidney is at first a distinctly lobulated body, and shows at birth, and sometimes

even in the adult, traces of its original subdivision into lobules. Each lobe corresponds to a medullary pyramid of the adult and its surrounding cortex. As the ureter increases in length, it becomes separated from the Wolffian duct, and acquires a distinct opening into the anterior part of the cloaca nearer the head of the embryo than that of the Wolffian duct. This part of the cloaca receiving the ureters becomes the bladder.

Bladder.—The bladder is formed from the upper part of the anterior subdivision of the cloaca (Figs. 780 and 781), which increases in width as the openings of the ureters become shifted further from one another. Inferiorly the anterior part of the cloaca remains narrow, and is continuous with the upper part of the urogenital canal. At a very early stage the triangular surface, known in the adult as the **trigonum vesicæ**, is to be recognised. From the cephalic end of the developing bladder the allantoic canal extends to the umbilicus; but the allantois loses its lumen in the fifth week, and the portion enclosed within the body of the embryo, and known as the **urachus**, becomes converted into the fibrous cord found in the adult connected with the bladder apex.

The cavity of the allantois is sometimes not lost so early, and in rare cases it has been found persisting in the child or adult as a pervious channel extending from the apex of the bladder to the umbilicus. Here it may open on the surface of the body.

By some authorities the bladder is stated to arise as a dilatation of the proximal part of the allantois rather than from the cloaca itself. The distinction, however, does not seem to be important, and probably both the cloaca and the allantois share in its formation.

Male Urethra.—The urethra in the male is composed of two parts which are developmentally distinct. One of these corresponds to the **prostatic** and **membranous** portions of the adult, and owes its origin to the *endodermal* cloaca, while the other part corresponds to the **spongy portion** of the adult, and arises in connexion with the *ectodermal* cloacal fossa and sexual eminence (Fig. 782). The upper part of the prostatic urethra has an origin similar to that of the bladder, and is derived from the upper portion of the urogenital subdivision of the cloaca; the lower prostatic and the membranous parts are formed from the urogenital canal of the embryo. The spongy portion of the adult urethra

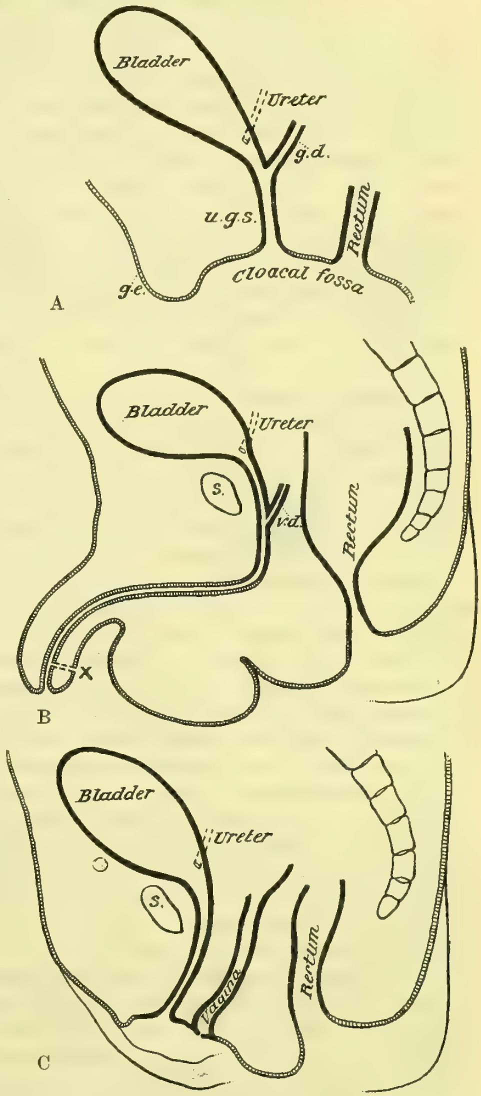


FIG. 782.—DIAGRAMMATIC REPRESENTATION AND COMPARISON OF THE MANNER IN WHICH THE UROGENITAL PASSAGES ARISE IN THE TWO SEXES.

In each case the hypoblast is indicated by a thick black line, while the epiblast is shown by a double line with cross shading.

A. Represents a stage passed through by both sexes, and illustrates the connexions of the urogenital ducts and of the rectum with the ectodermal cloacal fossa; *gd*, indicates the position where the Wolffian and Müllerian ducts open into the urogenital canal; *ge*, genital eminence; *ugs*, urogenital canal.

B. Male condition. The greater portion of the urethral canal is ectodermal in origin, and is derived from the ectodermal cloacal fossa and the groove on the genital eminence by the meeting of their lateral boundaries. (The portion of the canal which is usually the last to be closed in is indicated at *x*.) The upper part of the urethra is hypoblastic in origin. The position where the genital ducts (in the male represented by the vasa deferentia and uterus masculinus) join the urogenital canal is indicated at *vd*; *s*, symphysis pubis.

C. Female condition. Owing to the shortening of the urogenital canal (*ugs*, in A) the urethral and genital openings come to lie in the bottom of the urogenital fissure. The deepest part of this fissure, immediately surrounding the openings, is formed by hypoblast derived from the urogenital canal.

is developed superficial to the cloacal membrane which separates the ectodermal cloacal fossa from the endodermal cloaca. This ectodermal part of the urethral canal is formed by the meeting of the lateral boundaries of the cloacal fossa, where they lie in front of the anal opening, and also by the closing of the lips of a groove which appears on the sexual eminence. The lateral boundaries of the fossa, fusing in the middle line, close in the portion of the canal which in the adult is surrounded by the corpus spongiosum, while the portion which traverses the glans penis (*i.e.* the fossa navicularis) is formed from the groove which appears on the sexual eminence. The median raphe, extending from the anus forwards along the urethral surface of the penis in the adult, indicates the line of fusion along which the spongy part of the urethra has been closed in and converted into a canal. The last portion of the fossa to be closed in is the extreme anterior part which lies just at the base of the glans. In some rare cases failure of the margins of the fossa to unite in this situation causes the urethra to appear to terminate at this point. In other cases a greater arrest of development leaves the cloacal fossa open, and we have a condition maintained which resembles to a certain extent the normal arrangement in the female. To such abnormalities of the urethra the term **hypospadias** is applied.

Female Urethra.—In the female the urethra is developed from the part of the anterior portion of the cloaca which lies below the developing bladder, and above the openings of the Müllerian and Wolffian ducts. The part below these openings, the urogenital canal, during the course of development becomes shorter and shorter, and finally forms the epithelium at the bottom of the urogenital cleft immediately surrounding the urethral and vaginal openings. Thus in the adult the urethra, which originally led into the urogenital canal, opens into the urogenital fissure.

In some mammals, such as the hedgehog, the shortening of the urogenital canal does not take place in the female during development, and in these animals a single aperture exists for the urinary and genital systems. The hymen is placed where the fused Müllerian ducts (vagina) open into the urogenital canal.

Sexual Glands.—In the development of the sexual glands, male and female, a differentiated thickened portion of the peritoneal epithelium is first recognised. This specialised epithelium, which has received the name of **germinal epithelium**, is situated to the inner side of the mesonephros and of the Wolffian and Müllerian ducts. Here it covers a longitudinally-disposed ridge or elevation called the **genital ridge**. The germinal epithelium is not strictly limited to this ridge, but extends to some extent beyond its limits. The genital ridge is soon found to have numerous epithelial cells embedded in its connective-tissue stroma which appear to originate, in both sexes, by a proliferation from the deep surface of the germinal epithelium covering the ridge. From these epithelial cells the seminal tubules of the male, and Graafian follicles with their contained ova of the female are developed.

In the male, as early as the thirty-third day, the epithelial cells embedded in the stroma of the developing testis have become arranged into a network of anastomosing cords within which certain larger cells are seen to be irregularly scattered. These larger cells have received the name of **primitive sperm cells**, and are relatively few in number. They undergo frequent division, and are in the later stages not to be distinguished from the other cells of the cords. The cellular cords undergo direct transformation into the **seminal tubules** of the testis, but the excretory apparatus, including the **rete testis** and **tubuli recti**, is derived by outgrowths from the anterior tubules of the mesonephros. At a very early stage the superficial part of the stroma, of the developing testis, becomes denser, and gives origin to the **tunica albuginea**.

It has been stated that the sexual epithelium of the testis, unlike that of the ovary, is not derived from the germinal epithelium, but that it has its origin in an outgrowth of the mesonephros. The course of the development of the sexual glands is without doubt extremely difficult to follow.

In the female large epithelial cells are found in the stroma of the developing ovary, beneath the germinal epithelium, as early as the thirty-third day. These **primitive ova** are much more numerous than the primitive sperm cells of the male, and form a very characteristic feature of the developing ovary. At first they lie isolated, but later—about the fifth week—they become surrounded by other smaller cells having a like origin from the germinal epithelium. Each primitive ovum surrounded by its cells becomes a **primitive follicle,** the further development of which has already been described (p. 1125). The proliferation of cells from the germinal epithelium goes on until the seventh month, and during the later stages the epithelium has the appearance of growing down into the stroma in the form of long branching cellular processes which break up into little nests of

cells to form the future follicles (p. 1125). It is extremely doubtful if any new ova arise after birth.

Generative Ducts.—As has been already stated, the male ducts arise from the Wolffian and the female from the Müllerian ducts of the embryo. Both sexes at first possess well-developed Wolffian and Müllerian ducts, which are arranged in a very definite manner. The Wolffian ducts communicating directly with the tubules of the mesonephros lie at first parallel to, and at a considerable distance from one another. As they pass backwards to the caudal end of the embryo they approach one another, and each becomes enclosed in a fold of peritoneum called the **plica urogenitalis**. The ducts, which soon become closely approximated to each other, are embedded in a cord-like mass of connective tissue, to which the term **genital cord** is applied. They finally open into the lower part of the anterior subdivision of the cloaca.

The Müllerian ducts, opening freely into the body cavity at their cephalic ends, lie to the outer side of the Wolffian ducts. As they are traced caudally they cross the Wolffian ducts and enter the genital cord, within which they unite and form a canal, which occupies the mesial plane, and opens into the lower part of the anterior subdivision of the cloaca, between the Wolffian ducts. The manner in which the ureters become separated from the Wolffian ducts has already been described.

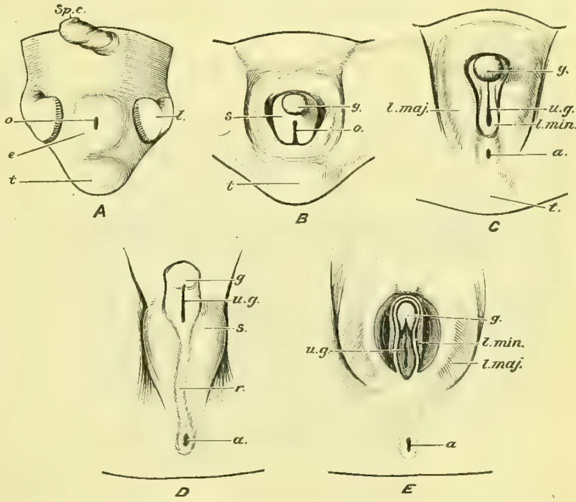


FIG. 783.—THE DEVELOPMENT OF THE EXTERNAL GENITAL ORGANS. From the models by Professor Ecker.

A. Slit-like ectodermal cloaca *o*, bounded on each side by an elevation, *e*.

B. The genital eminence *g*, lies anterior to the opening of the fossa; *s* indicates the inner genital fold, to the outer side of which the labio-scrotal fold is seen.

C. Female—after complete separation of the rectum from the urogenital portion of the cloacal fossa. The urogenital portion of the fossa is bounded on each side by the labium majus and the labium minus.

D. Male—closing in of the urogenital portion of the ectodermal cloaca and of the groove on the sexual eminence to form the spongy portion of the urethra. Origin of the penis and scrotum.

E. Female—the urogenital portion of the ectodermal cloaca remains open and forms the greater part of the urogenital cleft of the adult.

a. Anus.
e. Wall of cloacal fossa.
g. Genital eminence or glans.
l. Lower limb.
l.maj. Labium majus.
l.min. Labium minus.
o. Opening of cloaca.
r. Raphe.
s. Inner genital fold in B, and scrotum or labio-scrotal fold in D.
Sp.c. Umbilical cord.
t. Tail.
ug. Urogenital portion of cloaca or opening into it.

Ducts in the Male.—The seminal tubules of the testis become connected with the Wolffian duct by a fusion of the anterior canals of the mesonephros with the **seminal tubules**. At the place where this fusion occurs the **rete testis** and **tubuli recti** are formed. The connexion is definitely established in the third month. The number of tubules taking part varies considerably, but corresponds to the number of **vasa efferentia** found in the adult. The connecting tubules becoming much convoluted, just as they join the Wolffian duct, form the **coni vasculosi**. The **canal of the epididymis** is directly formed from the anterior part of the Wolffian duct, and the **vas deferens** from the more posterior portion. The **ductuli aberrantes** and the rudimentary tubules of the **organ of Giraldés** are to be looked upon as persistent tubules, of a more posterior portion of the Wolffian body, which have failed to become connected with the tubules of the testis. The **seminal vesicles** which arise in the third month are developed as evaginations from the Wolffian ducts, near their caudal extremities. From the part of the cloaca into which the Wolffian ducts open the prostatic urethra of the adult is derived. The Müllerian ducts atrophy in the male embryo, but the **hydatids** of the epididymis and of the testis are rudimentary remains of their anterior portions, while the **sinus pocularis** represents the lower fused portions which, in the embryo, occupy the genital cord.

Ducts in the Female.—The Müllerian ducts in the female retain their openings into the body cavity, and their anterior portions become the Fallopian tubes. Their

fused posterior parts, which at first open into the urogenital canal, give rise to the **uterus** and **vagina.** The manner in which the original position of the opening of the Müllerian ducts becomes shifted, by the shortening of the urogenital canal, so as to appear at the bottom of the urogenital fissure, has already been described.

The vaginal portion of the fused Müllerian ducts is at first relatively very short, and at the point where it opens into the urogenital canal a slight fold appears, which is the future **hymen.** The vagina increases rapidly in length as its opening moves downwards towards the urogenital cleft.

The Wolffian ducts and the mesonephros atrophy in the female, but traces of them are to be found in the longitudinal canal of the parovarium and paroophoron of the adult. In the fœtus the Wolffian duct can be traced along each side of the uterus as far as the upper end of the vagina.

Prostate.—The glandular portion of the prostate arises as a series of solid outgrowths from the epithelium of the urogenital canal during the third month. The outgrowths, which are at first simple, become branched and finally acquire a lumen. They are arranged in three groups—an upper and a lower dorsal group, and a ventral. The glands of the ventral group soon become reduced in number and often completely disappear.

Cowper's glands are also developed from the epithelium of the urogenital canal.

The **glands of Bartholin** arise as outgrowths from the epithelium of the urogenital canal.

External Genital Organs.—The external genital organs are developed in the region of the ectodermal cloacal fossa, and those of the male and female can only be distinguished from one another after the ninth week. The fossa is at first shallow, but soon, by the formation of prominent lateral boundaries, it becomes much deeper. These lateral eminences receive the name of **outer genital** or **labio-scrotal folds,** and enclose between them the **genital eminence** and the urogenital opening (Fig. 783). The urogenital opening is at this time a mesial cleft and its margins form a second pair of much smaller folds called the **inner genital folds.** The genital eminence which is situated at the upper or anterior end of the fossa, appears very early, even before the cloaca becomes divided into rectal and urogenital subdivisions. Its summit is somewhat enlarged, and its posterior surface presents a groove which leads into the urogenital opening. The genital eminence gives origin to the terminal portion of the **clitoris** in the female and of the **penis** in the male, the enlarged extremity becoming the **glans** in each case. In the female the interval between outer genital folds becomes the **urogenital cleft** of the adult, the outer folds the **labia ma'ora,** and the inner folds the **labia minora.** The groove on the posterior aspect of the clitoris becomes closed, but does not form a canal. In the male, on the other hand, the cloacal fossa becomes roofed over by the meeting together of its lateral boundaries to enclose a canal which becomes the spongy part of the urethra. The outer genital folds, meeting in a median raphe, form the **scrotum.** The groove on the posterior aspect of the genital eminence becomes by the fusion of its margins the terminal portion of the male urethra.

THE MAMMARY GLANDS.

The **mammary glands** (mammæ) or breasts are accessory organs connected with the female reproductive system. Each gland is situated in the superficial fascia covering the anterior aspect of the thorax, and usually extends from the level of the second to that of the sixth rib. The hemispherical projection formed by the gland lies upon the superficial aspect of the pectoralis major and to a small extent upon the serratus magnus muscle. Near the summit of each mammary elevation, and usually at the level of the fourth rib, is placed the wart-like **nipple** (papilla mammæ), which is pierced by the minute openings of the lactiferous ducts and surrounded by a coloured circular area called the **areola.** The skin covering the nipple is thrown into numerous wrinkles, while on the areola there are many minute rounded projections due to the presence beneath of cutaneous glands. These have received the name of **Montgomery's glands** or **glandulæ areolares,** and are considered to represent rudimentary portions of the mammary gland. The colour of the nipple and areola varies with the complexion of the individual, but in young subjects they are usually of a somewhat rosy-pink colour, which changes to a deep brown during the second and third months of first pregnancy. During pregnancy

also the areola increases in size and its glands become more marked. The nipple contains a considerable number of unstriped muscle fibres, and becomes firmer and more prominent as a result of mechanical stimulation.

The size and appearance of the mammary glands vary much, not only in the different races of mankind, but also in the same individual under different conditions. In the young child the mammæ are small, and there is little difference in the male and female. Their growth is slow until the approach of puberty, and then the female mammæ increase rapidly in size. At each pregnancy the mammæ become large, and they attain their greatest development during lactation. The size of the mamma depends partly on the amount of superficial fat and partly on the amount of glandular tissue present.

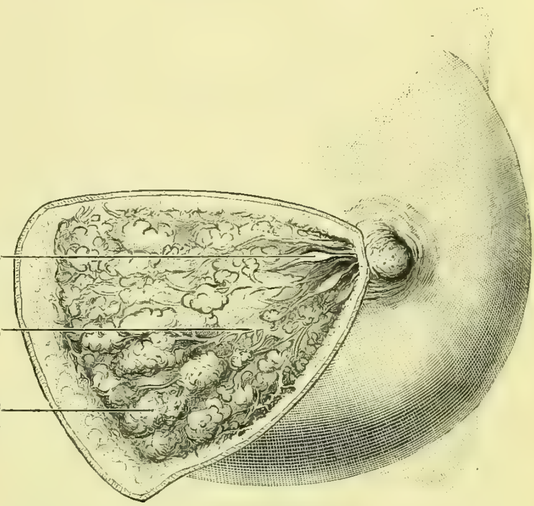


FIG. 784.—DISSECTION OF THE MAMMARY GLAND.

Structure of the Mamma.—The mamma is composed of a mass of glandular tissue traversed and supported by strands of fibrous connective tissue, and covered by a thick layer of fat. The glandular tissue, to which the term **corpus mammæ** is applied, forms a somewhat conical mass whose apex corresponds to the position of the nipple, while its base is loosely connected to the fascia covering the pectoralis major. In section the corpus mammæ is readily distinguished from the surrounding fat by its firmer consistency and by its pinkish-white colour. The corpus mammæ is composed of lobes and lobules, and its superficial aspect and edges are very uneven—the inequalities of its surface being filled up by processes of the fatty tissue which forms a covering for the gland. This covering is incomplete beneath the areola, where it is pierced by the lactiferous ducts as they pass into the nipple. The gland is composed of fifteen to twenty **lobes** (lobi mammæ) which radiate from the nipple, each lobe being quite distinct from the others and possessing its own duct. The lobes are subdivided into secondary lobes and lobules, bound together and supported by a considerable amount of connective tissue which forms the **stroma** of the gland.

The alveoli of the gland and the secretory epithelium lining them vary much under different conditions. At puberty the corpus mammæ is chiefly composed of connective-tissue stroma and the ducts of the gland. At this time the alveoli are small and few in number. During lactation, when the gland is fully functional the alveoli are enlarged, distended with fluid, and much more numerous. The epithelial cells are cubical and filled with fat globules. When the gland is not secreting the alveoli become small and reduced in number, while the cells of the lining epithelium, which are now small and granular, do not contain fat globules.

The duct (ductus lactiferi) of each lobe, passing towards the nipple, becomes enlarged to form a small spindle-shaped dilatation called an **ampulla or sinus lactiferi**; then becoming once more constricted, it passes, without communicating with the other ducts, to the summit of the nipple, where it opens.

In the male subject the various parts of the mamma are represented in a rudimentary condition.

The presence of milk glands is characteristic of the class mammalia, and the number of pairs of glands in each group of animals bears some relation to the number of young usually produced at each birth.

Variations.—Asymmetry in the development of the mammæ is very common—the left mamma being very often larger than the right. Absence of one or both mammæ is a very rare abnormality, which may or may not be associated with absence of the nipples. When one

nipple only is present it is usually the left. The presence of supernumerary glands or nipples is not so uncommon, and a very large number of examples are recorded. The term **polymasty** has been applied to cases in which more than the normal number of mammæ are present, and **polythely** to those in which additional glands, in a rudimentary condition, are represented by accessory nipples. Usually the accessory glands, or nipples, are present on the ventral aspect of the thorax, and in most instances they occur below and a little to the inner side of the normal site. When the abnormal glands are found above the normal site they generally lie further from the middle line. Much more rarely accessory glands have been found on the abdomen, in the axilla, or in some other situation, including even the dorsal aspect of the trunk. As many as three extra pairs of mammæ have been found in the same individual, and cases in which the probable representatives of mammary glands were even more numerous have been recorded. Asymmetry is very common in these abnormal structures. It is interesting to note that examples of polymasty and polythely occur in the male almost as frequently as in the female. In some women the accessory breasts have yielded milk during lactation; in other cases the abnormal organs have been very rudimentary, and represented only by a minute nipple or pigmented areola. These cases of polymasty and polythely are supposed to represent a reversion to an ancestral condition, in which more than two mammary glands were normally present, and in which probably many young were produced at each birth. In this connexion it is interesting to observe that usually the accessory glands occur in positions normally occupied by mammæ in lower animals. In the course of development of the mammary glands in man, specialised areas of the epidermis, similar to those which give origin to the mammary glands, have been observed both above and below the region in which the adult mammary glands are developed. These areas appear to be present normally, but in most cases they disappear at an early stage in the history of the embryo. In some other mammals rudimentary mammary glands may occur, as, for instance, in lemurs and in some cows.

A slight functional activity of the mammary glands of the male at birth and about the time of puberty is not a very uncommon occurrence.

Vessels and Nerves of the Mamma.—The breast receives its arterial supply from the perforating branches of the **internal mammary artery** and from the **external mammary branch** of the long thoracic. Additional supply is sometimes derived from some of the intercostal vessels. The veins coming from the gland pour their blood into the **axillary** and **internal mammary veins.** Some small superficial veins from the breast join tributaries of the external jugular. The **lymphatics** of the breast are very numerous, and form extensive lymph spaces round alveoli of the gland. The lymphatic vessels coming from the mamma for the most part join the lymphatic glands of the axilla, but some vessels from the inner part of the breast, following the course pursued by the perforating arteries, join the lymphatic glands situated along the course of the internal mammary artery. The nerve supply of the gland is derived from the **intercostal nerves** of the fourth, fifth, and sixth intercostal spaces. Along the course of these nerves sympathetic filaments reach the breast from the dorsal part of the sympathetic cord.

DEVELOPMENT OF THE MAMMÆ.

The mammary glands are developed as downgrowths of the epidermis into the underlying mesoblastic tissue. In the human embryo a thickened raised area of the epidermis is to be recognised in the region of the future mammary gland at the end of the fourth week. This thickened epiblast becomes depressed in the underlying mesoblast, and thus the mammary area soon becomes flat, and finally sunk below the level of the surrounding epidermis. The mesoblast, where it is in contact with this downgrowth of the epiblast, is compressed, and its elements become arranged in concentric layers, which at a later stage give rise to the connective-tissue stroma of the gland. The depressed mass of epiblastic cells soon becomes somewhat flask-shaped, and grows out into the surrounding mesoblast as a number of solid processes, which represent the future ducts of the gland. These processes, by dividing and branching, give rise to the future lobes and lobules, and much later to the alveoli. The mammary area becomes gradually raised again in its central part to form the nipple. A lumen is only formed in the different parts of this branching system of cellular processes at birth, and with its establishment is associated the secretion of a fluid resembling milk, which often takes place at this time. The ampullæ appear as thickenings on the developing ducts before birth.

In those animals which possess a number of mammary glands—such as the cat, pig, etc.—the thickening of the epiblast, which is the first indication of the development of these structures, takes the form of a pair of ridges extending from the level of the fore-limb towards the inguinal region. These converge posteriorly, and at their terminations lie not far from the middle line. By the absorption of the intermediate portions the ridges become divided up into a number of isolated areas, in connection with which the future glands arise. Such linear thickenings of the epiblast have not yet been shown to occur in the human embryo, but the usual positions assumed by the accessory glands when present, leads one to suspect that in all probability the ancestors of man possessed numerous mammary glands arranged, as in lower animals, in lines converging when traced towards the inguinal region.

THE DUCTLESS GLANDS.

By D. J. Cunningham.

Under this title we include a heterogeneous group of organs, the common feature of which is that the products of their activity are not conveyed from them by means of ducts, but are discharged directly into the vascular system through the veins or lymphatic vessels which take origin within them. This physiological process is termed *internal secretion*, and in the case of certain of these organs the secretion has been shown to exert a profound influence upon the nutritive changes of the body.

The ductless glands include the lymphatic glands, which have been already described with the vascular system; the pineal and pituitary bodies, which have been referred to in the account which has been given of the brain; and the spleen, the suprarenal capsules, the thyroid body, the parathyroids, the thymus body, the coccygeal body, the carotid body—all of which still remain to be studied.

THE SPLEEN.

The **spleen** (lien) is the largest of the ductless glands. It varies greatly in size in different individuals, and also in the same individual under different conditions, consequently it is difficult to give its average dimensions. Roughly speaking, it may be said to be as a rule about five inches in length and three inches in width at its widest part. It is a soft yielding organ, very vascular, and somewhat purple in colour. It lies far back in the abdominal cavity between the stomach and the diaphragm, and its position is such that, whilst the greater part of the organ is situated in the left hypochondrium, its upper end extends inwards beyond the left Poupart plane, and thus comes to lie in the epigastric region. It is placed very obliquely, and its long axis corresponds closely in its direction to that of the back part of the tenth rib.

Form of Relations of the Spleen.—The spleen has the shape of an irregular tetrahedron. The upper end or **apex** (extremitas superior) points inwards and backwards, and is curved to some extent forwards on itself. Of the four surfaces the most extensive is the **diaphragmatic** (facies diaphragmatica), which looks backwards and outwards. It rests upon the back part of the diaphragm, to the curvature of which it is accurately adapted. By the diaphragm it is separated from the ninth, tenth, and eleventh ribs. It is necessary also to remember that the pleura descends between this portion of the chest wall and the diaphragm, and thus comes to lie superficially to the greater part of this diaphragmatic surface of the spleen. The thin basal margin of the lung, which occupies the upper part of the pleural recess, likewise intervenes between the upper part of the spleen and the surface of the body.

In the fœtus and infant, in which the liver is relatively very large, the left lobe of that organ extends to the left so far that it comes as a rule to intervene between a portion of the spleen and the diaphragm. Such a relation is sometimes seen in the adult, but, except in childhood, it is usual for the liver to fall short of the spleen.

The remaining three surfaces of the spleen are turned towards the cavity of the abdomen, and are closely applied to the viscera which support the organ in its place. These three surfaces, which may be grouped together under the one term of *visceral aspect* of the organ, are separated from each other by three ridges which radiate from a blunt and somewhat inconspicuous prominence which may be termed the **internal basal angle**. One of these ridges, a salient and prominent border (margo intermedius), extends to the upper end of the spleen, and separates an extensive anterior gastric area from a narrower posterior renal area. A second short border passes backwards to the **posterior basal angle**, and intervenes between the renal and basal surfaces; whilst the third ridge, often obscurely marked, proceeds forwards to the **anterior basal angle** and separates the gastric and the basal surfaces from each

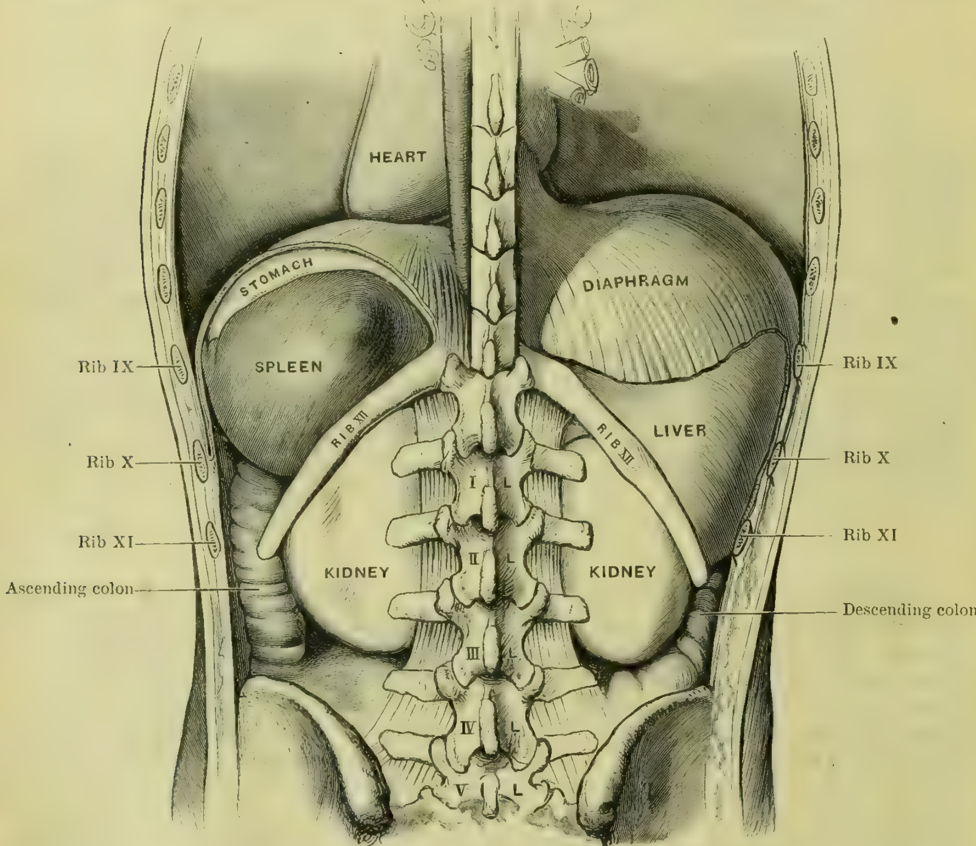


FIG. 785.—DISSECTION OF THE SPLEEN, LIVER, AND KIDNEYS FROM BEHIND, IN A SUBJECT HARDENED BY FORMALIN-INJECTION.

other. The term basal surface is applied to a triangular area which is mapped out by the two last-named ridges together with the lower border of the organ.

The **gastric surface** (facies gastrica) is the most extensive of the three visceral districts. It is deeply concave, and is moulded on the fundus of the stomach. Within its area, and about an inch or so in front of the margo intermedius, is the **hilus** of the organ. This is a slit, frequently broken up into two or more pieces, which gives passage to the vessels and nerves which enter and leave the spleen. Behind the hilus, and immediately in front of the internal basal angle, there is a depression of variable extent and depth into which the tail of the pancreas is received.

The **renal surface** (facies renalis) is flat and even. It is applied to the anterior surface of the upper part of the kidney, close to its outer border. Sometimes the part of this surface which adjoins the apex or upper end of the organ is applied to the left suprarenal capsule, but as a rule it falls short of that structure.

The **basal surface** (facies basalis) is the smallest of the three visceral areas. It

is triangular in form, and looks downwards and inwards, and is in contact with the splenic flexure of the colon and the costo-colic ligament (*vide* p. 1033).

The **anterior border** (margo anterior) of the spleen is sharp and prominent, and intervenes between the gastric and diaphragmatic surfaces. Its leading characteristic is that it is irregularly notched. The **posterior border** (margo posterior) separates the renal from the diaphragmatic surface. It is important to know that, if in the living subject the finger is drawn along the last intercostal space, it will indicate with tolerable accuracy on the surface of the body the position and direction of the posterior border. The **inferior border** (margo inferior) of the spleen intervenes between the diaphragmatic surface and the basal surface. The other margins of the spleen are those which separate the visceral areas from each other, and they have been already noticed.

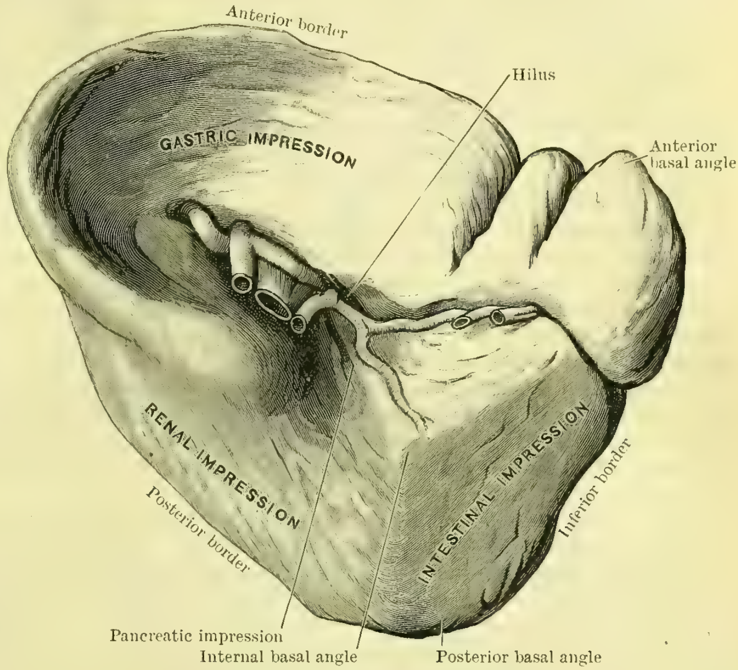


FIG. 786.—THE SPLEEN—VISCERAL ASPECT.

A marked feature of the typically-formed spleen is the great prominence of the **anterior basal angle**. It forms the most anteriorly placed part of the organ.

Peritoneal Relations of the Spleen.—The spleen is almost completely enveloped by peritoneum, and two folds of peritoneum, viz. the gastro-splenic omentum and the lieno-renal ligament, pass from it. Both of these folds are attached in the neighbourhood of the hilus. The **lieno-renal ligament** proceeds backwards to the anterior surface of the left kidney (p. 1049); the **gastro-splenic omentum** connects the spleen with the fundus of the stomach (p. 1054).

Accessory Spleens.—Small globular masses of splenic tissue are not infrequently found in the neighbourhood of the spleen. These are termed **accessory spleens.**

Blood-vessels, Lymphatics, and Nerves of the Spleen.—The large **splenic artery** gains the spleen by passing between the two layers of the lieno-renal ligament. It breaks up into several branches which enter the organ through the hilus. Some twigs proceed from the splenic artery to the stomach, which they gain by insinuating themselves between the two layers of the gastro-splenic omentum. The **splenic vein** is formed in the lieno-renal ligament by the union of the branches which emerge from the hilus of the organ. It joins the superior mesenteric vein to form the vena portæ.

The **splenic plexus of nerves** is an offset from the cœliac part of the solar plexus, and accompanies the arteries into the spleen.

The **lymphatic vessels** leave the spleen at the hilus, and accompany the great vessels. There are no lymphatic channels within the spleen, although they are present in its capsule (Mall).

Structure of the Spleen.—In our study of the structure of the spleen we have to consider—(1) the tunica propria, (2) the trabecular framework, (3) the spleen pulp, and (4) the distribution of the blood-vessels and the Malpighian corpuscles.

Tunica propria (tunica albuginea).—Subjacent to the serous coating furnished by the peritoneum the spleen is provided with a strong capsule termed the tunica propria. This is formed of fibrous tissue, with a large proportion of elastic fibres and a certain amount of involuntary muscular tissue. It is therefore highly distensible, and perhaps feebly contractile. To the outer surface of this capsule the peritoneum is inseparably attached.

Trabecular Framework (trabeculæ lienis).—From the deep surface of the tunica propria numerous processes or trabeculæ are given off, and these penetrate into the substance of the spleen. Some are cord-like, others are in the form of flattened bands, and all are composed of fibrous tissue and involuntary muscular fibres. Within the spleen the trabeculæ branch and re-branch, and join with each other to form a supporting framework for the organ. The blood-vessels, as they enter at the hilus, carry in with them connective-tissue sheaths, and these also take part in the formation of the trabecular framework.

Spleen Pulp (pulpa lienis).—The interstices between the strands of the trabecular framework are filled with spleen pulp. This is supported by a delicate reticulum formed by branching cells. The spaces of the network freely communicate, and are occupied by blood in which there are large numbers of leucocytes, and also large cells special to the spleen. These are termed **splenic cells**, and contain pigment, and not infrequently red blood corpuscles in their interior.

Blood-vessels and Malpighian Corpuscles.—The splenic arteries, as they traverse the spleen, run in the trabeculæ. The small branches ultimately leave these and enter the spleen pulp. As they do so they become ensheathed in a coating of adenoid tissue. At certain points in the course of the arteries this sheath suddenly increases in thickness, and forms small round or oval masses of adenoid tissue upon the vessel. In sections through the spleen these small nodular masses are visible to the naked eye as minute white spots. They are called **Malpighian corpuscles** (noduli lymphatici lienales). The artery rarely passes through the centre of such a corpuscle. As a rule the adenoid tissue is massed chiefly upon one side of the vessel, and a plentiful supply of blood is given to the nodule by means of a capillary network in connexion with the artery on which the Malpighian corpuscle is developed.

The manner in which the minute terminal arteries end in the spleen pulp is peculiar. The wall becomes reduced to the endothelial lining, and the cells forming this gradually separate from each other and become continuous with those of the reticulum of the spleen pulp. The blood therefore flows directly into the meshes of the reticulum of the pulp. The minute radicles of the veins begin in the same way as the arteries end. The walls are gradually built up by the union of cells continuous with the open reticulum, and the blood flowing into the vessels so formed is led away towards the larger veins which occupy the trabeculæ.

Development of the Spleen.—It is not until the second month of intrauterine development that the spleen begins to develop. It is formed from mesoderm, and appears in the dorsal mesogastrium in the neighbourhood of the pancreas. After a short time it becomes invaded by blood-vessels, but the Malpighian corpuscles are somewhat late in making their appearance. The spleen grows to the left in the direction of least resistance, protruding the left layer of the mesogastrium before it, and its form is determined by the pressure to which it is subjected by the neighbouring viscera and the abdominal wall.

THE SUPRARENAL CAPSULES.

The suprarenal capsules (glandulæ suprarenales) are two small flattened organs which lie in the epigastric region, one on either side of the spine, and in intimate relation to the upper end of the corresponding kidney.

The **right suprarenal capsule** is, as a rule, triangular in form, and rests by its base upon the anterior and inner aspect of the upper end of the right kidney. It is placed between the posterior surface of the right lobe of the liver and that portion of the diaphragm which covers the side of the spine.

The *anterior surface*, which looks outwards as well as forwards, presents two impressions—(1) The one is a narrow flattened strip adjoining the anterior border of the capsule which is overlapped by the inferior vena cava; (2) the second impression comprises the remainder of the anterior surface, and is in contact with the liver. Only a small and variable part of the lower portion of the anterior surface of the right suprarenal capsule is covered by peritoneum. On the upper part of the impression for the vena cava, not far from the apex of the capsule, a short fissure termed the **hilus** may be observed. From this issues a short wide vein which immediately enters the vena cava inferior. The *posterior surface* of the right suprarenal capsule is divided by a salient curved ridge into an upper flat part, which is applied to the diaphragm, and a concave lower part, which is occupied by fat and rests upon the kidney.

The **left suprarenal capsule** presents a semilunar form, and as a rule is slightly larger than the right capsule. Its position on the kidney is also somewhat different. It is usually placed on its inner border immediately above the hilus. The

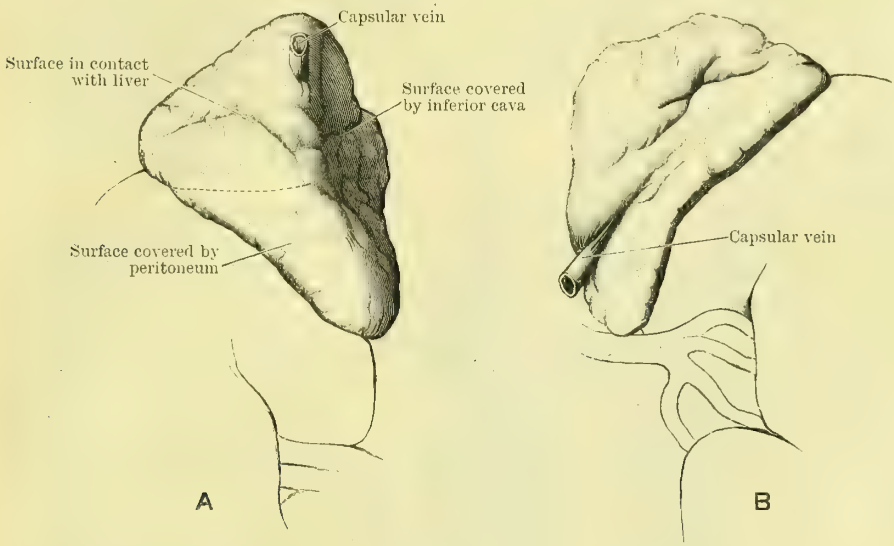


FIG. 787.

A. Anterior surface of right suprarenal capsule. B. Anterior surface of left suprarenal capsule. The upper and inner parts of each kidney are indicated in outline. On the right capsule the dotted line indicates the upper limit of the peritoneal covering.

anterior surface presents, not far from its lower end, a very obvious **hilus** with a large emerging vein. The greater part of this surface is in relation to the posterior aspect of the stomach, and forms a portion of the bed in which that organ lies. This gastric area of the suprarenal capsule is clothed by peritoneum derived from the lesser sac. The lower portion of the anterior surface is covered by the pancreas and crossed by the splenic vessels, and is not in relation to the peritoneum. Sometimes the spleen extends inwards so as to lie in relation to the upper part of the

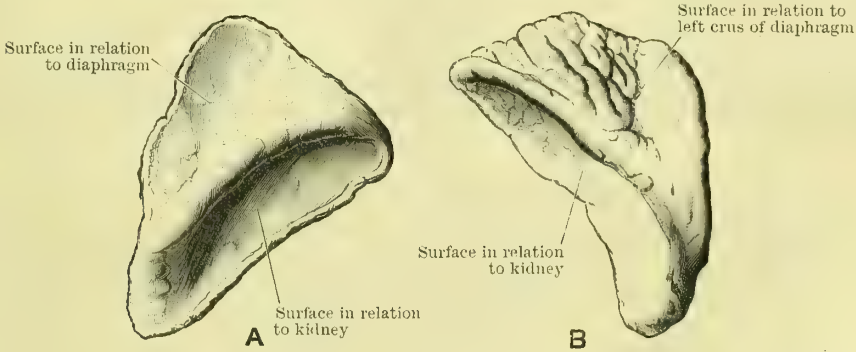


FIG. 788.

A. Posterior surface of right suprarenal capsule. B. Posterior surface of left suprarenal capsule.

anterior surface of the left suprarenal capsule, but this cannot be said to be the rule. The *posterior surface* is subdivided into two areas, as on the right side, by a curved ridge. The upper area is flat, and applied to the left crus of the diaphragm; the lower area is hollowed out, and is in relation to the kidney, a considerable amount of fat intervening.

In the fœtus the suprarenal capsules are relatively very much larger than in the adult. Indeed, on the left side the capsule extends downwards on the kidney so far that the spleen is completely shut out by it from that organ.

Vessels of the Suprarenal Bodies.—Each capsule receives three arteries—viz. from the inferior phrenic, from the aorta, and from the renal artery. One large vein, emerging from the hilus on

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the anterior surface, as a rule conveys all the blood from the organ. On the right side it opens at once into the inferior vena cava, and on the left side into the left renal vein.

The **nerves of the suprarenal bodies** are very numerous. They come from the solar plexus, and constitute the suprarenal plexus.

Structure of the Suprarenal Capsule.—The suprarenal capsule is surrounded by a thin connective-tissue sheath, from the deep surface of which fine processes are given off which enter the substance of the organ, and form within it a supporting stroma or framework.

The gland-substance is composed of—(1) an external cortical portion, firm in consistence, of a yellowish hue, and forming the chief bulk of the organ; and (2) an internal medullary part, very soft and pulpy, and dark brown in colour.

The **cortical substance** (substantia corticalis) consists of groups of cells occupying the interstices of the stroma. These cell-groups present different forms at different levels from the surface. Thus, subjacent to the connective-tissue sheath, there is a thin stratum, termed the *zona glomerulosa*, in which the cell masses are more or less rounded; next comes the *zona fasciculata*, which constitutes the chief part of the cortex, and in which the cells are grouped in long columns which are arranged radially with reference to the surface; and lastly, there is the deepest layer, the *zona reticularis*, in which the cells are disposed in a reticular manner amidst the stroma.

The **medullary part** (substantia medullaris) is also pervaded by a fibrous stroma continuous with that of the cortex. This forms an irregular meshwork, the spaces of which are occupied by cells of very variable shape and somewhat similar to epithelium in appearance.

The arteries enter the cortex and break up into capillaries which are arranged around the cell-groups. In the medulla there are large thin-walled capillaries into which the whole blood of the organ passes. These capillaries are closely surrounded by the medullary cells. Proceeding from them are the radicles of the capsular vein.

Development of the Suprarenal Capsule.—Several observers ascribe a totally different origin to the cortical and medullary parts of the suprarenal body. According to these authorities the **medulla** is derived as a column of cells which grows out from the sympathetic cord, and becomes in the process of development encapsulated within the cortex. That a portion of the sympathetic enters the suprarenal capsule would appear to be undoubted, but that it forms the medulla is questionable. Gottschaw and Janosik hold that the medullary cells are in reality derived by a metamorphosis of the cortical cells.

The **cortical part** of the suprarenal body is formed from a mass of mesodermic cells which become grouped together in the immediate vicinity of the inferior vena cava soon after that vessel is formed. The cells thus accumulated together are said to be derived directly or indirectly from the epithelial cells which line the body cavity. Janosik and Mihalkovics believe that they come from the germ epithelium which covers the preaxial part of the genital ridge. According to Weldon, however, they owe their origin to columns of cells which grow out from the Malpighian glomeruli of the preaxial part of the Wolffian body.

THE THYROID BODY.

The **thyroid body** (glandula thyreoidea) is a highly vascular, pliant structure which clasps the upper part of the trachea and extends upwards for some distance upon each side of the larynx. In size it varies greatly in different individuals, and in the female and child it is always relatively larger than in the adult male. It consists of three well-marked subdivisions—viz. two lateral lobes, joined across the middle line by the isthmus.

Each **lateral lobe** is conical in form. Its base extends downwards upon the side of the trachea as far as the fifth or sixth tracheal ring, whilst its apex rests upon the ala of the thyroid cartilage. Its *superficial surface* is somewhat flattened, and is clothed by the pretracheal layer of cervical fascia, from which the organ derives a sheath, and also by the sterno-thyroid, sterno-hyoid, and omohyoid muscles. It is also overlapped by the sterno-mastoid muscle. Its *deep surface* is adapted to the parts upon which it lies—viz. to the side of the trachea, to the cricoid cartilage, and to the inferior cornu and adjoining part of the surface of the ala of the thyroid cartilage; whilst its *posterior border* extends backwards so as to touch the œsophagus and pharynx and overlap the common carotid artery (Fig. 626, p. 924).

The **isthmus** of the thyroid body is a narrow band of varying width which lies

in front of the second, third, and fourth rings of the trachea, and unites the bases or lower ends of the two lateral lobes.

A third lobe is frequently found in connexion with the thyroid body. This is the **pyramidal or middle lobe** (Fig. 790). When present it assumes the form of an elongated slender process which springs from the upper border of the isthmus on one or other side of the mesial plane (more usually on the left side) and extends upwards for a variable distance towards the hyoid bone upon the cricoid and thyroid cartilages. A strand of fibrous tissue, or perhaps a narrow slip composed of muscular fibres (levator glandulæ thyreoideæ), connects it to the body of the hyoid bone.

The thyroid body is firmly attached to the parts on which it lies, and therefore follows the larynx in all its movements.

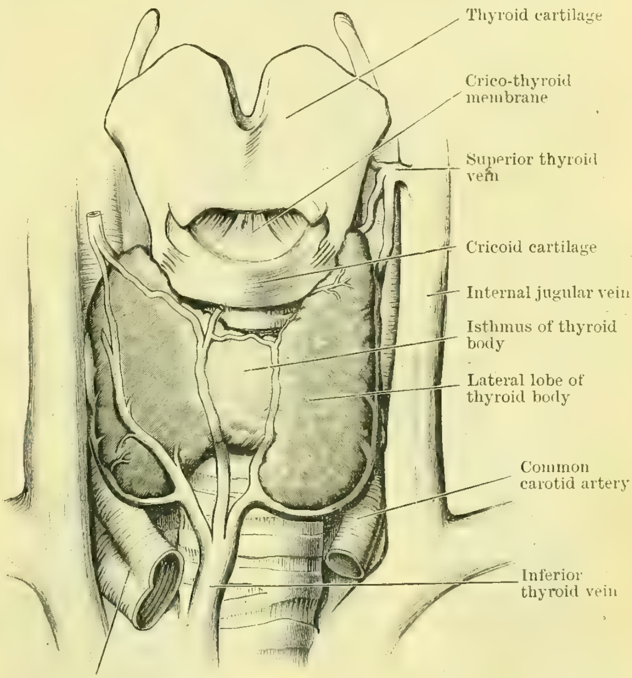

FIG. 789.—DISSECTION OF THE THYROID BODY AND OF THE PARTS IN IMMEDIATE RELATION TO IT.

Variations.—Small detached portions of the thyroid tissue placed in the neighbourhood of the lateral lobes or in the vicinity of the hyoid bone are not uncommon. Such glandular masses are termed **accessory thyroid bodies.** The isthmus is the part of the organ which is most subject to variation. Its size differs greatly in different individuals, and it not infrequently happens that it is absent.

Blood-vessels.—Four large **arteries,** and occasionally a fifth smaller vessel, convey blood to the thyroid body. Two **superior thyroid branches** spring from the external carotid arteries. Each of these divides at the apex of the lateral lobe into three branches for its supply. Two **inferior thyroid branches** from the thyroid axis of the subclavian artery distribute their terminal branches to the basal portions and deep surfaces of the lateral lobes. The occasional artery is the **thyroidea ima,** a branch of the innominate, which ascends upon the trachea to reach the isthmus of the thyroid body. The thyroid arteries anastomose freely with each other.

The **veins** which drain the blood from the thyroid body are still more numerous. They are three in number on each side—viz. the **superior** and **middle thyroid veins,** which join the internal jugular; and the **inferior thyroid,** which descends in front of the trachea and joins its fellow of the opposite side to form a large common stem which opens into the left innominate vein. Numerous large veins ramify on the surface of the organ and lie in grooves in its substance. It is from this plexus that the inferior thyroid veins take origin.

The **nerves** which go to the thyroid body accompany the vessels. They are derived from the middle and inferior cervical ganglia of the sympathetic.

Structure of the Thyroid Body.—The thyroid body is enveloped by a closely applied thin capsule of connective tissue. From the deep surface of this numerous processes penetrate into the substance of the organ, and divide it into lobes and lobules. From the septa which separate the lobules fine lamellæ proceed which form the boundaries of vast numbers of closed vesicles or alveoli of different sizes and shapes. Some of the vesicles are spherical or polyhedral, whilst others are oval or flattened and branching. All are lined by a layer of cubical or columnar epithelial cells, and most of them contain a viscid semi-fluid colloid material.

The blood-vessels traverse the organ in the fibrous-tissue septa, whilst the capillary network is disposed on the outer surface of the various vesicles. Numerous lymphatic vessels arise external to the alveoli, and Baber has shown that they frequently contain colloid material similar to that in the interior of the vesicles.

Development of the Thyroid Body.—The thyroid body is formed from three

originally separate and distinct rudiments which arise independently of each other—viz. a median rudiment and two lateral rudiments.

The **median thyroid rudiment** arises as a hypoblastic evagination or tubular diverticulum from the floor or ventral wall of the pharynx (Fig. 28, F.C, p. 35). The point at which this occurs is in front of the second visceral arches, at the junction between the basal portion of the tongue and that part of the organ which is developed from the tuberculum impar (see pp. 36 and 963). The foramen cæcum on the dorsum of the adult tongue represents the upper persistent part of the median thyroid diverticulum. The median thyroid rudiment is at first in the form of a short hypoblastic outgrowth which extends downwards towards the front of the larynx. It rapidly elongates, and its terminal extremity bifurcates and comes to lie in front of the upper part of the trachea. This bifurcated extremity forms the isthmus of the thyroid body, and probably also a portion of each lateral lobe. The portion of the diverticulum which intervenes between the foramen cæcum and the isthmus is termed the **thyro-glossal duct.** It very early loses its lumen, and becomes converted into a solid cord of epithelial cells. The lower part of this usually persists as the **pyramidal lobe**, whilst the remainder becomes broken up into detached parts. Certain of these fragments may persist as accessory thyroid glands, and indicate the course pursued by the original thyro-glossal duct. Cases in which portions of the thyro-glossal duct not only persist but remain patent occasionally occur. The rare occurrence of a **lingual duct**, which extends from the foramen cæcum downwards through the tongue towards the hyoid bone, is accounted for in this manner.

The **lateral thyroid rudiment** of each side arises as a saccular hypoblastic diverticulum from the pharyngeal side of the fourth visceral cleft (see p. 34). It comes into relation with the lateral aspect of the larynx, and becoming cut off from the cavity of the pharynx, it joins with the isthmus or median rudiment to form the greater part of the lateral lobe of the thyroid body.

The thyroid body in its primitive condition and in each of its three parts is epithelial. Soon it is invaded by connective tissue and blood-vessels, but the hypoblastic epithelium is retained as the cellular lining of its constituent vesicles.

Parathyroids.

The **parathyroid glands** are two minute structures which lie in more or less close relation to each lateral lobe of the thyroid body. They are apt to be mistaken for accessory thyroids, but in structure they are different. One, more constant in position than the other, is situated on the posterior aspect of the œsophagus at the level of the lower border of the cricoid cartilage, and in more or less intimate relation to the posterior border of the lateral lobe of the thyroid body. The second parathyroid body is placed either in close apposition with the lower border of the lateral lobe of the thyroid, or on the trachea at a varying distance below it. The inferior thyroid artery intervenes between the two parathyroid bodies (Welsh).

The parathyroid bodies are composed of epithelial cells, and in structure bear a close resemblance to the anterior lobe of the pituitary body. It has been shown that the removal of the four parathyroids from the cat is followed by very severe symptoms, and in two cases out of three death ensued in the course of a few days (Welsh).

THYMUS GLAND.

The **thymus gland** can only be studied to advantage in the later period of fœtal life or in early childhood. It attains its maximum development towards the end of the second year, and from this time on it dwindles away until very little of it is left. In the new-born child it is of a pinkish colour, and is composed of two lateral lobes, separated by an intervening fissure, which are very seldom of equal size. The main portion of the gland is placed within the thorax, but the two lobes end above in two blunt prolongations which are carried upwards for a varying distance into the neck.

The thoracic portion of the thymus gland, in its fully-developed condition, is placed in the superior and anterior mediastinal spaces, and as a rule it extends downwards as far as the level of the fourth costal cartilages. The mediastinal pleura and lung are applied to it on either side, whilst the sternum and costal cartilages are in close relation to it in front. The deep surface of the thymus is

moulded upon the pericardium and upon the vessels in the front part of the superior mediastinum. Thus, when it is hardened *in situ* and removed, it presents on its posterior surface a deep pericardial concavity, with impressions on the upper part of this hollow corresponding to the pulmonary artery and vena cava superior (Fig. 791). Above the pericardial surface deep grooves indicate the intimate manner in which it is adapted to the two innominate veins. Above the left innominate vein the two lobes of the thymus ascend to an unequal height into the neck. They are placed in front of the trachea, and extend outwards so as to overlap the termination of the innominate artery on the right side and the left common carotid artery on the left side. One or other of the lobes may rise as high as the thyroid gland, but as a rule both fall somewhat short of this organ, and the lobe which ascends highest is usually attached to the corresponding lateral lobe of the thyroid body by a strand of connective tissue.

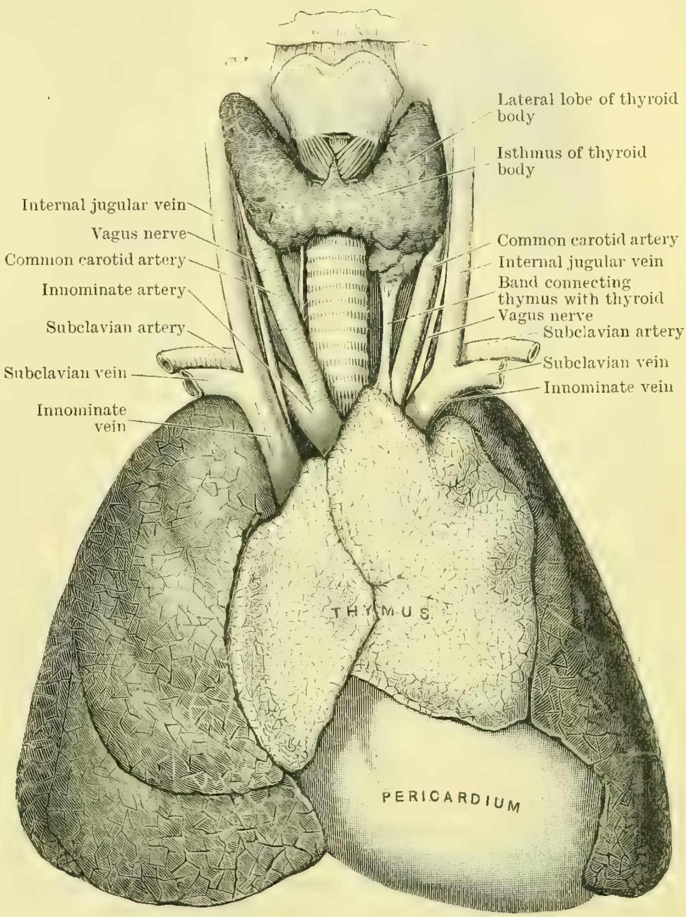

FIG. 790.—THYMUS GLAND IN A FULL-TIME FŒTUS HARDENED BY FORMALIN-INJECTION.

After the second year the thymus gland remains stationary, or it begins slowly to diminish in size, but when puberty is reached a rapid degeneration sets in. Its lobules become infiltrated with fat and loose strands of connective tissue. Waldeyer has shown, however, that throughout the whole of life it not only retains something of its old form, but also that the degeneration is never complete. Preserved within its substance (either uniformly diffused through it or in distinct masses) there may always be found remains of the original thymus-tissue.

Blood-vessels and Nerves.—The **arteries** which carry blood to the thymus come from the inferior thyroid, the internal mammary, and perhaps also from other sources. The **veins** join the neighbouring venous trunks—viz. the inferior thyroid, the internal mammary, and the two innominate veins.

The **nerves** to the thymus are derived from the vagus and sympathetic trunks.

The **lymphatic vessels** are of large size, and accompany the blood-vessels.

Structure of the Thymus.—The thymus is composed of a large number of small polyhedral lobules. The sheath which envelops the organ sends off from its deep surface fine partitions or septa which pass into the gland and separate the different lobules from each other.

Each lobule is composed of clusters of lymphoid follicles, with a small amount of delicate connective tissue intervening between them. A follicle consists of an outer **cortical** and an inner or central **medullary portion**. Both are formed of adenoid tissue,

but in the cortex the lymphoid cells are packed much more closely, whilst in the medulla the retiform matrix is coarser and the lymphoid cells less numerous. Further, the medulla contains the **concentric corpuscles of Hassall**. These are curious bodies, composed of flattened epithelial cells arranged concentrically around a granular nucleated corpuscle. A special developmental interest is attached to these concentric corpuscles.

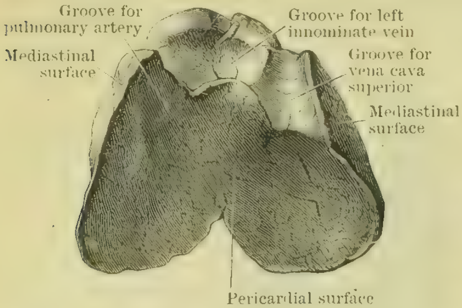

Fig. 791.—Deep Surface of Thymus Gland, taken from a Fœtus hardened by Formalin-injection.

The blood-vessels form a fine plexus around the various follicles, and from this capillaries penetrate into the central medulla.

Development of the Thymus Body.—The thymus gland is derived from the hypoblastic lining of the pharynx. It takes origin as a tubular diverticulum from the dorsal part of the pharyngeal aspect of the third visceral cleft on each side (see p. 34). This diverticulum has thick epithelial walls, and it grows by rapid proliferation of its cells. It extends downwards on the side of the trachea towards the pericardium, and coming into contact with the corresponding hypoblastic evagination of the opposite side, the two lobes of the organ are formed—one from each lateral diverticulum. The narrow upper part of the outgrowth remains for a time tubular, and connected with the pharyngeal cleft from which it originates. Ultimately this connexion is broken through, and the expanded lower end sends out solid bud-like branches after the manner of an acinous gland.

Originally, therefore, the thymus gland is epithelial in its structure. Soon, however, it becomes invaded by connective tissue and quantities of adenoid tissue, so that ultimately it is transformed into the lymphoid organ characteristic of the child. The remains of the original epithelial constituents are to be seen in the concentric corpuscles of Hassall.

THE CAROTID AND COCCYGEAL BODIES.

The **carotid gland** is a minute oval reddish-brown body placed on the deep aspect of the common carotid artery at the point where it bifurcates into its two terminal branches. It is closely connected with the sympathetic nerve filaments which twine around the carotid vessels, and numerous minute arterial twigs enter it. In structure the carotid body is composed of nodular masses of polyhedral epithelial-like cells, separated from each other by strands of connective tissue. Wide thin-walled tortuous capillaries are brought into intimate relation with the cells.

The **coccygeal gland** is a small body placed in front of the tip of the coccyx. Branches from the middle sacral artery enter it. Its structure is very similar to that of the carotid body.

SURFACE AND SURGICAL ANATOMY.

By Harold J. Stiles.

THE HEAD AND NECK.

THE CRANIUM.

Scalp.—The first and third layers of the scalp, namely, the **skin** and the **occipito-frontalis muscle**, are firmly united by fibrous processes which pass from the one to the other through the second or dense subcutaneous **fatty layer.** Intervening between these three layers and the pericranium is a loose **cellular layer** which supports the small vessels passing between the scalp proper and pericranium. The thin **pericranium**, although regarded anatomically as periosteum, possesses very limited bone-forming properties; over the vertex it is readily separated from the skull-cap, except along the lines of the sutures, where it gives off intersutural processes to join the endosteal layer of the dura.

The free **blood-supply of the scalp** is for the purpose of nourishing its abundant hair follicles and glands. The main vessels lie in the dense subcutaneous tissue, and are superficial, therefore, to the occipito-frontalis. The arteries supplying the frontal region are derived from the internal carotid, while those for the remainder of the scalp spring from the external carotid. These two sets of vessels anastomose freely with one another, and freely also across the mesial plane; hence the failure of ligature of the external carotid to cure cirsoid aneurysm of the temporal artery.

Wounds of the scalp bleed freely, and the vessels are difficult to ligature on account of the adhesion of their walls within the septa of the dense subcutaneous tissue. In extensive flap wounds and in diffuse suppuration beneath the occipito-frontalis there is little danger of sloughing of the scalp. **Abscesses** and **hæmorrhages** superficial to the occipito-frontalis are usually limited on account of the density of the subcutaneous tissue. Hæmorrhage beneath the occipito-frontalis is seldom extensive on account of the small size of the vessels, but suppuration in this situation may rapidly undermine the whole muscle; incisions to evacuate the pus should be made early, and parallel to the main vessels of the scalp. Extravasation of blood beneath the pericranium leads to a hæmatoma which is limited by the sutures.

The **veins** of the scalp communicate with the intra-cranial venous sinuses—(1) directly through their anastomoses with the large emissary veins, namely, the parietal, which opens into the superior longitudinal sinus, and the mastoid and posterior condyloid, which open into the lateral sinus; (2) through the anastomoses of the frontal and supra-orbital veins with the ophthalmic vein, which opens into the cavernous sinus; (3) through the veins of the diploë, which connect the veins of the scalp and the pericranium on the one hand with those of the dura mater and the venous sinuses on the other; (4) through small veins which pass from the pericranium through the bones and the intersutural membranes to the dura. It is along these various channels that pyogenic infection may extend, from the scalp and pericranium, through the bone to the dura mater and venous sinuses, and from the latter to the cerebral veins, the pia-arachnoid, and the substance of the brain. More rarely the infection spreads from the cranial cavity along the emissary veins to the scalp.

The **lymphatics** of the anterior part of the scalp join the facial lymphatics; those of the temporal and parietal regions open into the pre-auricular and parotid lymphatic glands, situated in front of and below the ear, and into the post-auricular or mastoid glands, situated upon the insertion of the sterno-mastoid muscle. The lymphatics of the occipital region open into the occipital glands, which lie close to the occipital artery where it becomes superficial in the scalp.

Bony Landmarks of the Cranium.—At the root of the nose is the fronto-nasal suture **(nasion)**: a little above it is the **glabella,** a slight prominence which connects the superciliary ridges. About 1 in. below the posterior pole of the cranium, and 2 in. above the spine of the axis, is the external occipital protuberance **(inion).** In the child the protuberance is not developed; its position may be defined by taking a point at the junction of the upper and middle thirds of a line extending from the posterior pole of the skull to the spine of the axis. About a third of the distance from the nasion to the inion is the **bregma** or junction of the coronal and sagittal sutures; with the head in the natural erect posture the bregma corresponds to the middle of a line carried across the vertex between the pre-auricular points of the zygomatic arches.

At birth the position of the bregma is occupied by the **anterior fontanelle,** a rhomboidal membranous area which generally becomes ossified at about the eighteenth month. The size and date of closure of the fontanelle, as well as its tension and pulsation, are all points to be carefully noted in the clinical examination of children.

The **lambda,** or junction of the sagittal and lambdoidal sutures, situated $2\frac{1}{2}$ in. above the inion, can generally be felt through the scalp; a line drawn from it to the posterior border of the root of the mastoid process corresponds to the **lambdoidal suture.** In the adult the *parieto-occipital fissure* of the brain lies opposite, or a few millimetres in front, of the lambda; in the child, however, the fissure may be as much as 1 in. in front of it.

Crossing the supra-orbital margin close to its inner angle, a finger's-breadth from the middle line, are the **supra-trochlear nerve** and the **frontal branch of the ophthalmic artery**; the latter nourishes the flap in the operation of rhinoplasty. At the junction of the inner and middle thirds of the supra-orbital margin, 1 in. from the middle line, is the **supra-orbital notch** or **foramen,** the guide to the **supra-orbital vessels** and **nerves.** A little above the level of the outer canthus of the eyelid is the **fronto-malar suture,** immediately above which is the **external angular process** of the frontal bone. At the posterior end of the suture the **temporal branch** of the **orbital nerve** pierces the temporal fascia to reach the scalp. Half-an-inch above the suture is the **lower margin** of the **cerebral hemisphere**; while half-an-inch below the suture is a small *tubercle* on the posterior border of the malar bone; a line drawn from this tubercle to the lambda gives the line of the **parallel fissure** and of the **descending cornu** of the **lateral ventricle.**

The **zygomatic arch,** an important landmark, is horizontal when the head is in the natural position, and is on the same level as the lower margin of the orbit and the inion; its upper border is at, or not infrequently a little above, the level of the lower lateral margin of the hemisphere. The upper border of the zygoma may be traced backwards immediately above the tragus and the external auditory meatus to become continuous with the ridge formed by the **supra-mastoid portion** of the **temporal crest.** The part of the posterior root of the zygoma which lies immediately in front of the upper end of the tragus constitutes a valuable landmark which may with advantage be termed the **pre-auricular point** of the zygoma, while by the term **post-auricular point** is understood that point upon the supra-mastoid crest which lies immediately behind, and a finger's-breadth below, the upper attachment of the auricle. The **temporal vessels** and the **auriculo-temporal nerve** cross the zygoma at the pre-auricular point, and it is here that the pulsations of the temporal artery may be felt during the administration of an anæsthetic, or the vessel compressed for the purpose of checking bleeding from the temporal region of the scalp. The termination of the auriculo-temporal nerve in the neighbourhood of the parietal eminence is often the seat of a neuralgic pain in irritative conditions about the external auditory meatus, the latter being supplied by this nerve.

Two inches vertically above the pre-auricular point is the **lower end** of the **fissure of Rolando.** Two fingers'-breadth ($1\frac{1}{2}$ in.) vertically above the middle of the zygomatic arch is the **pterion** (spheno-parietal suture), a point which cannot be felt, but which is nevertheless of topographical importance, as it overlies the **Sylvian point** (the point where the Sylvian fissure breaks up into its three branches) and the **anterior branch** of the **middle meningeal artery.** A point three fingers'-breadth vertically above the middle of the zygomatic arch, on the left side, will mark the position of the centre of **Broca's convolution** (posterior extremity of the left inferior frontal convolution).

The **frontal eminence** (better marked in the child) overlies the **middle frontal convolution.** The **parietal eminence,** which varies considerably in the definiteness with which it can be recognised, overlies the **termination of the posterior horizontal limb** of the **fissure of Sylvius,** and therefore also the **supra-marginal convolution,** which is named by Turner the *convolution of the parietal eminence.* The part of the **temporal crest** which intervenes between the external angular process and the coronal suture lies a little above the level of the inferior frontal sulcus. The highest part of the temporal crest crosses the Rolandic area at the junction of its middle and lower thirds, that is to say, at the **junction of the motor areas for the arm and face.** In the child, the temporal muscle, which is relatively much smaller than in the adult, reaches only a short distance above the squamous suture, and, therefore, only as far as the level of the lower end of the fissure of Rolando.

The thickness of the skull-cap varies at different parts and in different individuals. The inner table is only half the thickness of the outer table, but both possess the same degree of elasticity. When the vault is fractured from direct violence, the inner table is more extensively fissured than the outer table because the elements of the latter are compressed, while those of the former are stretched apart. The weak areas at the base of the skull through which fractures are liable to extend are: in the anterior cranial fossa, the orbital plates of the frontal bone and the cribriform plate of the ethmoid; in the middle cranial fossa, the region of the glenoid fossa of the temporal bone, and of the foramen ovale of the sphenoid; in the posterior fossa, the cerebellar fossæ of the occipital bone. The strong petrous temporal is weakened by the tympanic cavity and by the deep jugular fossa.

Cranio-Cerebral Topography.—Of the many methods which have been devised for mapping out the relations of the cranial contents to the scalp, that introduced by Professor Chiene is, probably, the most useful from a clinical point of view; no figures or angles have to be remembered, and the primary surface lines are drawn from bony points which are not variable, whilst the secondary lines are drawn, for the most part, between mid-points of the primary lines. The method is as follows (Figs. 792 and 793):—

"The head being shaved, find in the mesial line of the skull between the glabella (G) and the external occipital protuberance (O) the following points:—

"First, the *mid-point* (M); second, the *three-quarter point* (T); third, the *seven-eighth point* (S).

"Find also the *external angular process* (E), and the *root of the zygoma* (pre-auricular point) (P), immediately above and in front of the external auditory meatus. Having found these five points, join EP, PS, and ET. Bisect EP and PS at N and R. Join MN and MR. Bisect also AB at C, and draw CD parallel to AM."

The line MA corresponds to the **superior** and **inferior precentral sulci,** and may therefore be termed the *pre-central line.* The *origins* of the **superior** and **inferior frontal sulci** may be indicated by trisecting MA at the points K and L, the latter point being at the level of the temporal crest.

The line ET, termed the *oblique* or *Sylvian line,* intersects the pre-central line at the point A, which corresponds to the **Sylvian point** of the **fissure of Sylvius** and to the **anterior division** of the **middle meningeal artery.** AC overlies the **posterior horizontal limb** of the **fissure of Sylvius,** which terminates at the level of the temporal crest, in the lower part of the triangle HCB. This triangle contains the parietal eminence, and may, therefore, be termed the *supra-marginal triangle.* The termination of the Sylvian line, at the three-quarter sagittal point T, overlies the **parieto-occipital fissure.**

By joining TR, RO, a triangle is mapped out which delimits the outer surface

of the **occipital lobe**; the line TR corresponds to the **lambdoidal suture**, while RO corresponds to, or lies a little above, the **tentorium** and the upper border of the **lateral sinus**.

CD, the *post-central line*, corresponds to the **superior postcentral sulcus**, and lies a little behind the **inferior postcentral sulcus**.

The parallelogram AMDC overlies the **Rolandic area**, *i.e.* the ascending frontal and the ascending parietal convolutions, separated by the fissure of Rolando.

The pentagon ABRPN maps out the **temporal lobe**, with the exception of its

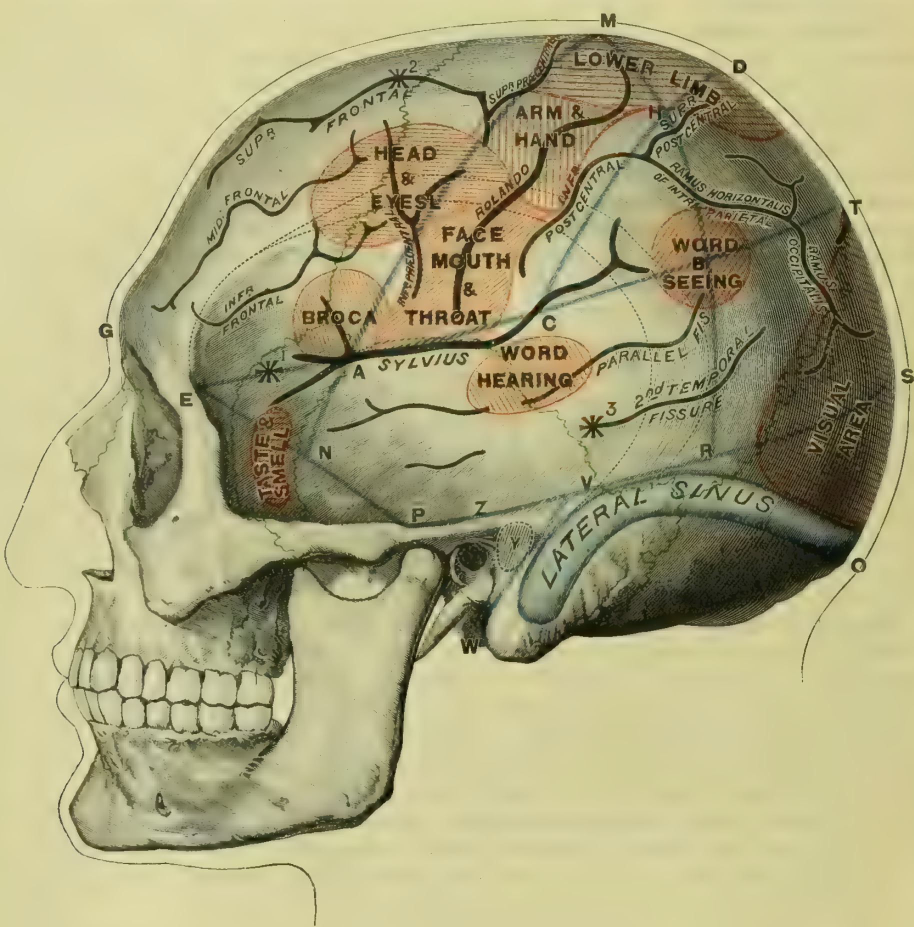

FIG. 792.—CRANIO-CEREBRAL TOPOGRAPHY.

Shows relations of the motor and sensory areas to the convolutions, and to Chiene's lines.

G. Glabella.
O. Inion.
M. Mid-point between G and O.
T. Mid-point between M and O.
S. Mid-point between T and O.
E. External angular process.
P. Root of zygoma (pre-auricular point).
N. Mid-point of EP.
R. Mid-point of PS.
C. Mid-point of AB.
CD is drawn parallel to AM.
Z. Post-auricular point.
VW. Guide to anterior limit of lateral sinus.
Y. Mastoid antrum.
*1. Site at which subarachnoid space may be opened.
*2. Site for draining lateral ventricle (Kocher).
*3. Site for draining lateral ventricle (Keen).

apex, which is directed downwards, forwards, and inwards, a finger's-breadth in front of the point N.

A finger's-breadth below AB is the **parallel sulcus**, the posterior extremity of which turns upwards to terminate at B, the point which indicates, therefore, the position of the **angular gyrus**.

The **fissure of Rolando** may be mapped out upon the scalp by drawing a line downwards and forwards for a distance of $3\frac{3}{8}$ in. from a point half-an-inch behind

the mid-sagittal point M at an angle of 67° to the sagittal line (Hare). This angle may readily be found by Chiene's plan of folding a sheet of paper first to half a right angle and again to a quarter of a right angle (45° + 22·5° = 67·5°). According to Cunningham, the average angle which the fissure makes with the sagittal line is 70°.

The **lateral ventricle** may be tapped or drained at the commencement of the descending cornu, through the posterior half of the first temporal convolution, by

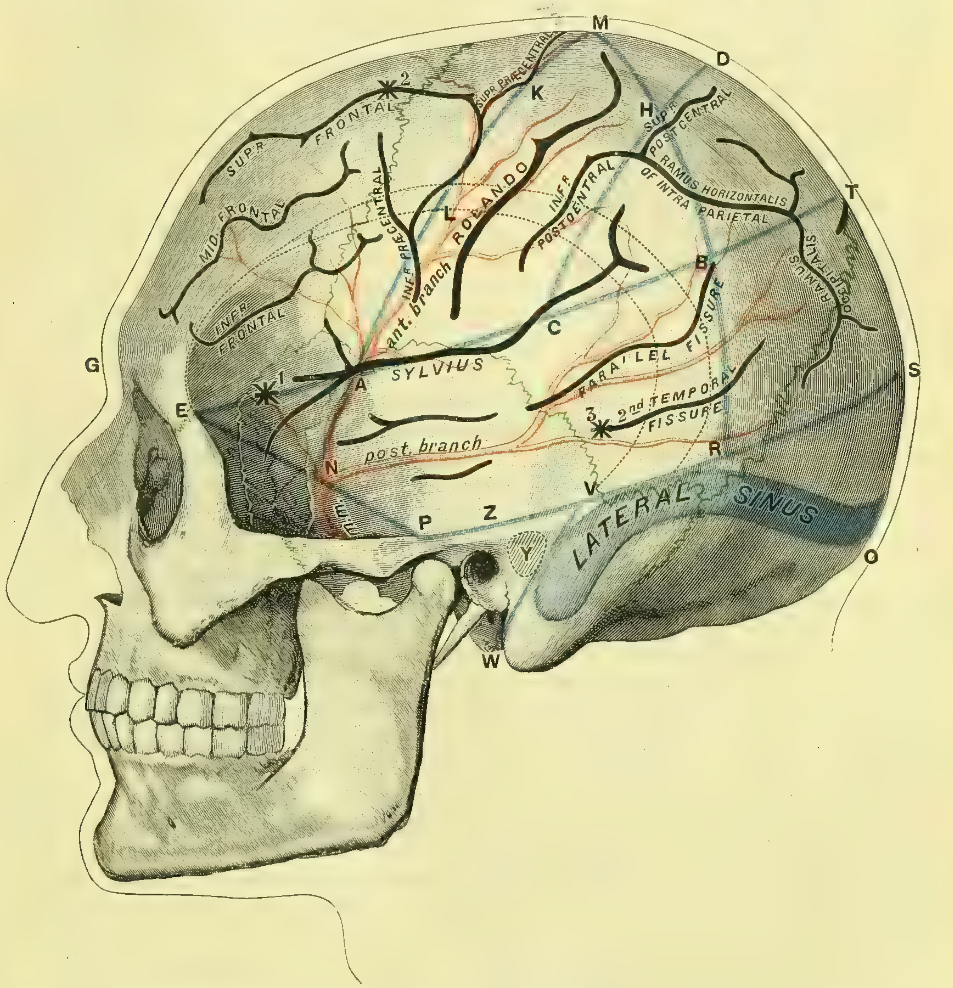

FIG. 793.—CRANIO-CEREBRAL TOPOGRAPHY.

Guiding lines (Chiene's), blue ; sutures, green ; meningeal arteries, red ; sulci, black.

G. Glabella.
O. Inion.
M. Mid-point between G and O.
T. Mid-point between M and O.
S. Mid-point between T and O.
E. External angular process.
P. Root of zygoma (pre-auricular point).
N. Mid-point of EP.
R. Mid-point of PS.
C. Mid-point of AB.
MA is divided into thirds at K and L.
CD is drawn parallel to AM.
Z. Post-auricular point.
VW. Guide to anterior limit of lateral sinus.
Y. Mastoid antrum.
*1. Site at which subarachnoid space may be opened.
*2. Site for draining lateral ventricle (Kocher).
*3. Site for draining lateral ventricle (Keen).

penetrating only 1 cm. of brain tissue. For this purpose the centre of the trephine should be placed a finger's-breadth below the middle of CB. Or, secondly, the ventricle may be reached from above, by traversing brain tissue for a depth of 4 to 5 cm. through the superior frontal sulcus, $1\frac{1}{4}$ in. (two fingers'-breadth) in front of the point K, the instrument being directed downwards and backwards (Kocher).

Keen drains the ventricles through an opening $1\frac{1}{4}$ in. behind the external auditory meatus and the same distance above Reid's base line (a line drawn backwards from the lower margin of the orbit through the centre of the external auditory meatus), the instrument being passed into the brain towards the summit of the opposite auricle. If the ventricle be not distended it will be reached at a depth of two inches from the surface.

To open the **subarachnoid space**, the pin of a small trephine is placed over the mid-point of the line EA; the subarachnoid is incised as it crosses the stem of the fissure of Sylvius from the frontal lobe to the anterior extremity of the temporal lobe. Care must be taken to keep in front of the middle meningeal artery.

The **cisterna magna**, situated between the back part of the under surface of the cerebellum and the medulla oblongata, may be reached by turning down a flap of soft parts, and removing a circle of bone a little above the foramen magnum, and immediately to one side of the middle line so as to avoid the occipital sinus. The **fourth ventricle** may be opened up by making a somewhat larger trephine opening in the mesial plane and separating the posterior extremities of the tonsillar lobes of the cerebellum.

To expose the **lateral hemisphere** of the **cerebellum**, trephine over the centre of a line drawn from the tip of the mastoid process to the external occipital protuberance. The occipital artery and the mastoid emissary vein will be divided in turning down the flap.

Meningeal Arteries.—When the calvarium is removed the **meningeal arteries** are found to adhere firmly to the dura. Of these vessels the middle meningeal artery is the only one of surgical importance. It is frequently lacerated in fractures of the skull; the blood is generally extravasated between the dura and the bone, and the bleeding point lies beneath the clot. After entering the cranial cavity through the foramen spinosum, the *main trunk,* which is usually about $1\frac{1}{2}$ in. in length, runs outward and slightly forwards to bifurcate into anterior and posterior divisions at a point a finger's-breadth above the middle of the zygomatic arch, viz. at or close behind the point N. When the main trunk is short the bifurcation is situated lower down and farther back.

The *anterior and larger division* passes upwards, with a slight forward convexity, a little behind the spheno-squamous suture and across the pterion to the anterior inferior angle of the parietal bone. From this point the vessel is continued upwards and slightly backwards behind the coronal suture; it gives off branches which ascend over the motor area. The position and general direction of the anterior branch may be readily mapped out on the surface, as it corresponds to the lower two-thirds of the precentral line MN; it follows, therefore, that the artery will be encountered in trephining over the lower and anterior part of the Rolandic area, especially over the motor centres for the tongue and face.

The *posterior division* passes almost horizontally backwards towards the posterior inferior angle of the parietal bone.

To expose the *trunk* of the vessel and its bifurcation, the trephine is applied immediately above the middle of the zygomatic arch. To expose the *anterior division* the pin of the trephine may be applied at the point A, which strikes the artery as it crosses the pterion and grooves the anterior inferior angle of the parietal bone. The lower segment of the disc of bone removed is much thicker than the upper, as it involves the prominent ridge which passes from the tip of the great wing of the sphenoid on to the anterior inferior angle of the parietal bone. At the anterior inferior angle of the parietal bone, the artery frequently runs in a canal for a distance of half an inch. It follows, therefore, that a considerable thickness of bone has to be sawn through at the lower segment of the circle before the disc can be removed, and during the removal bleeding may occur from the artery as it lies in the canal.

Vogt localises the *anterior division* at a point a thumb's-breadth behind the tubercle on the posterior border of the malar bone and two fingers'-breadth above the zygoma. Krönlein trephines at a point $1\frac{1}{4}$ in. behind the external angular process, on a line drawn from the supra-orbital margin backwards parallel to

Reid's base line. If the centre of the trephine be placed at the mid-point of the line LA the anterior division will be reached above the canal and the ridge at the anterior inferior angle of the parietal; should the bleeding-point be lower down the trephine opening may be enlarged downwards along the line MA.

The course of the *posterior division* may be indicated upon the surface by drawing a line backwards from the point M parallel to PR, that is to say, a finger's-breadth above the zygoma and the supra-mastoid crest.

When the **frontal branch** of the anterior division is injured, the clot is in the fronto-temporal region, and involves more especially the motor area for the face, and, on the left side, Broca's convolution; when the **anterior division** is wounded, the clot, which is larger, involves the parieto-temporal region, and the motor symptoms are due to pressure upon the centres for the arm and face; in injuries to the **posterior division** the clot overlies the parieto-occipital region, and the localising symptoms are sensory (Krönlein). In more extensive meningeal hæmorrhage the clot may cover the greater part of the hemisphere.

The **superior longitudinal sinus**, which enlarges as it extends backwards, occupies the mesial plane of the vertex from the glabella to the internal occipital protuberance, where it opens into the torcular Herophili, and becomes continuous usually with the right lateral sinus. Opening into the sinus, especially in the posterior part of the parietal region, are the **para-sinoidal sinuses**, into which Pacchionian glands project. In opening the skull over the posterior part of the vertex, the edge of the trephine should be kept at least three-quarters of an inch from the mesial plane.

The **lateral sinus** may be mapped out on the surface by drawing a line, slightly convex upwards, from a point a little above the level of the external occipital protuberance to the posterior inferior angle of the parietal bone, at, or a little in front of, the point R, which forms the *highest part* of the arch of the sinus; from this point the upper border of the sinus follows the line PR for a distance of one inch, and then curves downwards and forwards to a point $\frac{3}{4}$ in. below and behind the centre of the external auditory meatus, where it finally curves inwards and forwards to open into the jugular bulb, which occupies the jugular foramen. The *anterior border* of the *descending* or *mastoid portion* of the sinus may be mapped out by drawing a line VW from a point a finger's-breadth behind the post-auricular point of the temporal crest to the anterior border of the tip of the mastoid process. In wounds of the sinus the hæmorrhage is very free, owing to the inability of its walls to collapse, but the bleeding is easily controlled by plugging.

Of the **cerebral arteries**, the *middle* supplies almost the whole of the motor area, and one of its lenticulo-striate branches, which enters the brain at the anterior perforated space, is called "*the artery of cerebral hæmorrhage*" from the frequency of its rupture in apoplexy. The extravasated blood involves the motor part of the internal capsule. The postero-mesial central branches of the *posterior cerebral* artery, which enter the brain at the posterior perforated spot, supply the optic thalamus and walls of the third ventricle; hæmorrhage from one of these branches is apt to rupture into the ventricle. The postero-lateral central branches of the posterior cerebral artery supply the optic thalamus, and when one of these vessels ruptures the hæmorrhage is apt to invade the posterior or sensory part of the internal capsule.

Ear.—The skin covering the outer surface of the **auricle** is tightly bound down to the perichondrium, hence inflammations of it are attended with little swelling but much pain. The **posterior auricular artery**, which ascends along the groove at the posterior attachment of the auricle, is immediately anterior to the incision for opening the mastoid antrum.

The **external auditory canal**, the general direction of which is downwards, forwards, and inwards, possesses various curves of practical importance. The highest part of the upward convexity, which is also the narrowest part of the canal, is situated at the centre of its osseous portion; beyond this the floor sinks to form a recess in which foreign bodies are liable to be imprisoned. Of the two horizontal curves the outer is convex forwards, the inner concave forwards. The skin of the osseous portion of the canal is thin and fused with the periosteum, hence when

chronically inflamed it is liable to give rise to secondary periostitis and osseous narrowing of the canal.

The relations of the osseous walls of the canal are of importance to the surgeon. The whole of the upper wall and the upper half of the posterior wall, developed from the squamous portion of the temporal bone, consist of two layers of compact bone, an upper and a lower, which are continuous, the former with the inner table, the latter with the outer table of the skull. The upper plate passes inwards to the petro-squamous suture, where it becomes continuous with the outer edge of the tegmen tympani, which roofs over the tympanic attic and the mastoid antrum; the lower plate bends downwards and inwards at its deepest part to form the lower and outer wall of the tympanic attic and the anterior part of the outer wall of the antrum (Trautmann). It follows, therefore, that when the mastoid antrum is abnormally small, due to sclerosis of the bone, or when it is encroached upon by a far-forward lateral sinus, it, along with the tympanic attic, can be opened by perforating the junction of the upper and posterior walls of the osseous canal, the instrument being directed inwards and slightly upwards. Upon the upper and posterior segment of the external auditory process is the **supra-meatal spine**; this small but important process, developed from the squamous

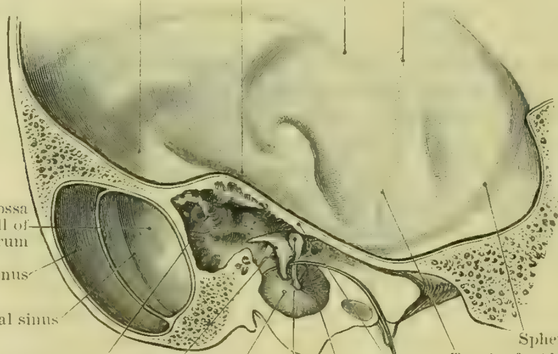

FIG. 794.—VIEW OF THE OUTER WALL OF THE MIDDLE EAR.

Section through the left temporal bone of a child, to show the relations of the middle ear and mastoid antrum to the middle and posterior fossæ of the skull.

portion, can usually be distinctly made out in the living subject by pressing upwards and backwards with the forefinger placed in the external auditory meatus.

The lower half of the posterior wall of the osseous canal (posterior part of the tympanic plate) is fused with the anterior part of the mastoid process, and closes the lower and anterior set of mastoid cells (border cells).

Anteriorly and inferiorly the osseous canal is related respectively to the **temporo-maxillary articulation** and the **parotid gland**; hence it follows that blows upon the chin may fracture the tympanic plate as well as the base of the skull, that pain on mastication is usually complained of in acute inflammatory affections of the meatus and middle ear, and that in young children, in whom the tympanic plate is incompletely ossified, suppurative inflammation is liable to extend from the ear to the parotid region.

Clinically, to obtain a view of the **membrana tympani** a speculum and a reflecting mirror are employed: the auricle is pulled upwards, backwards, and outwards, in order to straighten the cartilaginous part of the canal. The healthy membrane is pearly gray, semi-opaque, slightly concave outwards, and obliquely placed, being inclined outwards, especially above and behind.

The handle and short process of the malleus, both embedded in the membrana tympani, are the only objects distinctly seen when the healthy ear is examined with the speculum.

The short process of the malleus projects outwards, and presents itself, therefore, as a conspicuous object at the upper part of the membrane; passing forwards and backwards from this process are the **anterior** and **posterior folds** of the **membrana tympani**; they form the lower limit of Shrapnell's membrane, and correspond to the line of the chorda tympani nerve. The handle of the malleus, situated at the junction of the two upper quadrants, is seen passing downwards and slightly backwards to the point of maximum concavity of the membrane (umbo), situated a little below its centre; passing downwards and forwards from the umbo is the *triangular cone of reflected light*, to which too much importance must not be attached, since its appearances vary considerably in healthy ears. Normally, the long process of the incus is but faintly visible, and still less so are the promontory and foramen rotundum; in the condition of Eustachian obstruction, however, in which the membrane is indrawn, these structures, along with the folds of the drum, become more distinct.

In performing the operation of *paracentesis of the tympanic membrane* the postero-inferior quadrant is the site chosen for making the puncture, as, in addition to providing good drainage, it is farthest removed from important structures, especially the chorda tympani nerve.

In order to understand the clinical importance of the parts seen through the translucent membrane, it is necessary to study the relative position of the structure of the

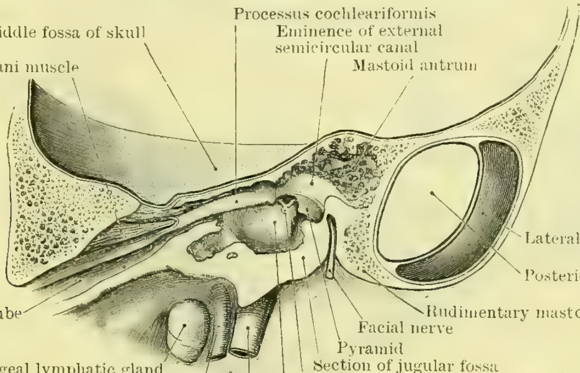

FIG. 795.—VIEW OF THE INNER WALL OF THE MIDDLE EAR.

Section through the left temporal bone of a child, to show the relations of the middle ear and mastoid antrum to the middle and posterior fossæ of the skull.

"*meso-tympanum*," that is to say, that part of the tympanum which lies opposite the tympanic membrane. If the tympanic plate and the tympanic membrane be carefully removed so as to leave the ossicles and chorda tympani nerve in position, it will be seen that the head of the malleus and the body and short process of the incus are altogether above the tympanic membrane, and that they occupy the **tympanic attic** or **epitympanic space**. At the junction of the two upper quadrants of the membrane is the **handle** of the **malleus**, which is directed downwards, backwards, and inwards. The **short process** of the **malleus** is directed outwards a little below the deepest part of the roof of the osseous external auditory canal. Opposite the postero-superior quadrant are the **long process** of the **incus**, which descends behind and almost parallel to the handle of the malleus, and the **stapes**, which is directed inwards and slightly backwards to the foramen ovale. The **chorda tympani nerve** runs from behind forwards between the outer surface of the upper part of the long process of the incus and the inner surface of the neck of the malleus. At the deepest part of the roof of the osseous canal above the chorda tympani nerve and the short process of the malleus is a notch (*notch of Rivini*), which is occupied by the flaccid and highest portion of the membrana tympani (*Shrapnell's membrane*). Opposite the postero-inferior quadrant of the drum-head is the **promontory** of the **cochlea**, below and behind which is the **foramen rotundum**. Opposite the antero-superior quadrant are the **processus cochleariformis**, the **tendon** of the **tensor tympani**, and the passage leading towards the **Eustachian tube**.

The *inner wall* of the tympanic cavity is related to the internal ear. The *upper wall* is separated from the middle fossa of the skull and the under surface of the temporal lobe of the brain by the **tegmen tympani**—a thin plate of bone, which is continued

anteriorly to form the roof of the osseous portion of the Eustachian tube, while posteriorly it roofs over the mastoid antrum. Externally the tegmen is limited by the **petro-squamous suture**, which may remain unossified for some years after birth, thus affording a channel along which pyogenic infection may spread from the middle ear to the meninges and brain. Infection may also spread along the small veins which convey blood from the tympanum to the superior petrosal and lateral sinuses.

The *floor* of the tympanum is formed mainly by the bone forming the **jugular fossa**, which is occupied by the bulb of the internal jugular vein. When the lateral sinus is large and unusually far forward the bulb is likewise large, and the fossa, which is consequently deeper, may arch up into the floor of the tympanic cavity, from which it may be separated merely by a thin and translucent plate of bone which occasionally shows an osseous deficiency. In cases where this condition existed the jugular bulb has been wounded in the operation of paracentesis of the tympanic membrane.

Anteriorly the tympanic cavity leads into the **Eustachian tube**, which brings it into communication with the naso-pharynx. In the child the Eustachian tube is shorter,

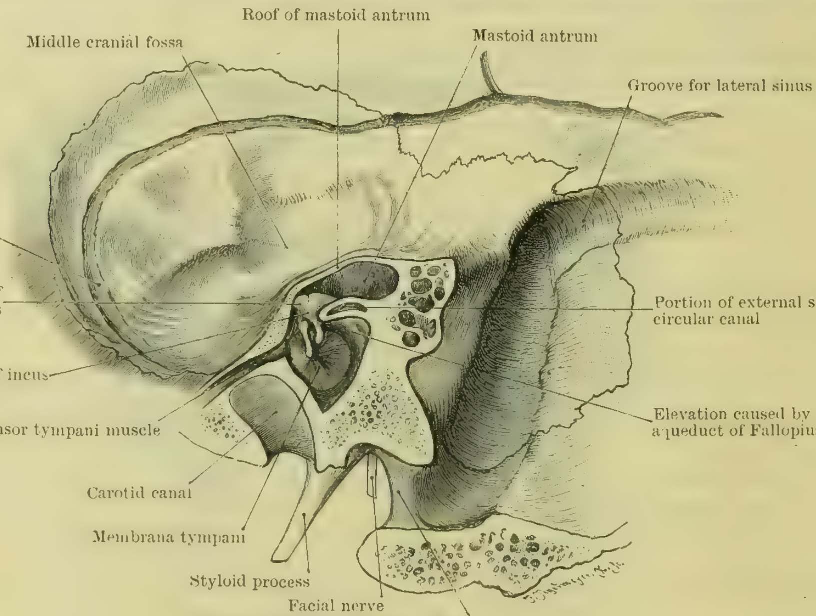

FIG. 796.—SECTION THROUGH PETROUS PORTION OF TEMPORAL BONE OF ADULT.

Showing the relation of the middle ear to the middle and posterior fossæ of the skull.

wider, and more horizontal than in the adult, hence inflammations are more liable to spread along it to the tympanum.

Above the level of the membrana tympani is the **tympanic attic** or **epitympanic space**, which communicates posteriorly by means of a triangular opening (*aditus ad antrum*) with the mastoid antrum; the base of the triangle, directed upwards, is formed by the tegmen tympani; its apex, directed downwards, is formed by the meeting of the inner and outer walls. The opening will admit an instrument half a cm. in diameter. The tympanic attic contains from before backwards the head of the malleus, the body and short process of the incus, the latter projecting backwards into the aditus. When these structures are covered with inflamed mucous membrane or granulations, drainage from the mastoid antrum into the tympanum proper is interfered with. The *boundaries of the aditus*, important surgically, are as follows: superiorly, the tegmen tympani; internally, an eminence of compact bone, containing the external semicircular canal, below and in front of which is a second smaller prominence, corresponding to that portion of the aqueduct of Fallopius which curves immediately above and behind the foramen ovale. The wall of the aqueduct is here thin and not infrequently deficient, in which case inflammation may readily spread from the tympanum to the facial nerve. The outer wall of the aditus is formed by the deepest part of the upper and outer wall of the osseous external auditory canal.

The *posterior wall* of the tympanum, below the aditus ad antrum, is formed by diplöic bone which contains the descending portion of the aqueduct of Fallopius.

The **mastoid antrum** is to be considered, developmentally as well as anatomically, as an extension upwards and backwards of the tympanum. Its anatomy and relations will be best understood by studying it in the child, in whom it is relatively larger than in the adult. Situated above and behind the tympanic cavity proper, its *outer wall* is formed by a triangular plate of bone which descends behind the external auditory process from the squamous portion. Posteriorly, this triangular plate is separated from the petro-mastoid element by the **petro-mastoid suture**, which overlies the posterior part of the antrum and transmits small veins to the surface. The suture does not become completely ossified until a year or two after birth, and remains of it may frequently be detected in the adult bone. The anterior and upper portion of the triangular plate turns inwards at an angle to form the upper and posterior wall of the rudimentary osseous canal, as well as the floor of the tympanic attic.

In the adult the outer wall of the mastoid antrum is formed by a plate of bone, from $\frac{1}{2}$ to $\frac{3}{4}$ in. in thickness, which occupies the triangular and somewhat depressed area between the ridge extending backwards and slightly upwards from the posterior root of the zygoma (supra-mastoid portion of temporal crest), and the upper and posterior quadrant of the osseous external auditory meatus; upon the latter is the **supra-meatal spine**, immediately behind which, upon the floor of the above triangle, is a crescentic depression, the **fossa mastoidea**. The outer wall of the antrum is felt through the skin as a slight depression immediately behind the auricle, and immediately below the ridge formed by the supra-mastoid crest; below the depression is the prominence corresponding to the insertion of the sterno-mastoid muscle. Trautmann has pointed out, however, that the supra-mastoid crest, which varies considerably in its obliquity, is sometimes situated a little above the level of the roof of the antrum, and that it is safer, therefore, to take the level of the upper border of the osseous meatus as the guide in order to avoid opening the middle fossa of the skull. In children the supra-mastoid crest is not developed, so that if the operator mistake the posterior root of the zygoma for the crest, he will open into the middle fossa of the skull immediately in front of the attic. The upper and posterior quadrant of the osseous meatus is, therefore, the only reliable guide to the antrum in the child.

The *inner wall* is formed by a thick plate of spongy bone which separates the antrum from that portion of the posterior fossa lying between the aqueduct of the vestibule and the groove for the sigmoid portion of the lateral sinus, and which contains the posterior semicircular canal.

The *roof*, which slopes downwards and forwards, is formed by the posterior and thinnest part of the tegmen tympani.

The *floor* is on a lower level than the aditus, and is therefore unfavourably placed for natural drainage.

The **mastoid process** begins to develop in the second year. As development advances the diplöe surrounding the antrum in the child becomes excavated to form the **mastoid cells**, which radiate from the antrum, and either directly or indirectly communicate with it by small openings. In the pneumatic type of mastoid the whole of the process is excavated by these cells, which extend upwards into the squamous portion, forwards to the posterior wall of the osseous meatus (border-cells), and backwards into the occipital bone. Pus retained within the "*border-cells*" may bulge into, and rupture through, the posterior wall of the osseous meatus. Less frequently the mastoid cells are absent, the bone consisting either of osseous tissue similar to that of the diplöe, or of dense bone (sclerosed type).

The mastoid process is grooved upon its inner surface by the sigmoid portion of the **lateral sinus**. The average distance of the foremost part of the sinus from the supra-meatal spine is 1 cm. The right sinus usually receives the superior longitudinal sinus, and when this is the case it is larger and farther forward than the left; in extreme cases it may reach to within 2 or 3 mm. of the meatus. The average minimum distance of the lateral sinus from the *outer* surface of the mastoid is about 1 cm., but when the sinus is large and far forward the thickness may be reduced to 1 or 2 mm.

The **facial nerve**, after entering the aqueduct of Fallopius at the bottom of the internal auditory meatus, lies immediately above and behind the foramen ovale, between it and the prominence of the external semicircular canal; thence it descends almost vertically in the posterior wall of the tympanum $\frac{1}{8}$ in. behind and internal to the lower half of the deepest part of the posterior wall of the external osseous canal, and emerges through the stylo-mastoid foramen (Fig. 515).

In the infant, in consequence of the absence of the mastoid process, the exit of the facial nerve from the stylo-mastoid foramen is unprotected and exposed upon the lateral rather than upon the basal surface of the skull at a point immediately behind the posterior segment of the tympanic horse-shoe. It follows, therefore, that, in infancy, the incision to expose the antrum should not be curved too far downwards and forwards, otherwise the facial nerve may be divided. In the infant the position of the mastoid antrum is relatively higher than in the adult,

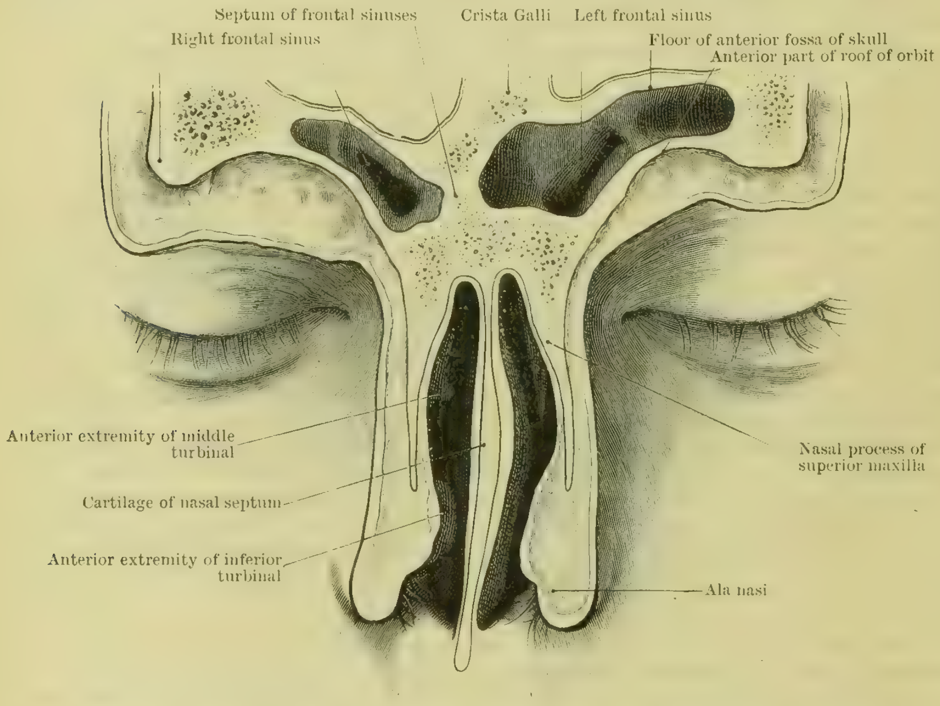

FIG. 797.—VERTICAL CORONAL SECTION THROUGH THE NOSE AND FRONTAL SINUSES.

because in the former the upper wall of the osseous canal inclines towards the vertical plane instead of being horizontal.

To open the **mastoid antrum** the surgeon makes a curved incision a little behind the attachment of the auricle, and chisels or drills away the bone immediately above and behind the postero-superior quadrant of the external osseous meatus. In this operation the *middle fossa* of the *skull* is avoided by keeping below the supra-mastoid crest, the *lateral sinus* by keeping close to the external auditory canal and by chiselling obliquely to the surface in opening the mastoid cells, the descending portion of the *facial nerve* is avoided by not encroaching upon the lower half of the deepest part of the posterior wall of the osseous canal. In extending the operation from the mastoid antrum through the aditus into the tympanic attic, the *external semicircular canal* and the curve of the *facial nerve*, which lie in relation to the inner wall of the aditus, are liable to injury, and must be protected either by a curved probe, or better by Stacke's protector, passed from the antrum through the aditus into the tympanic cavity.

The **frontal air sinuses** are two cavities situated immediately above the root of the nose between the two tables of the frontal bone. Each sinus at its most dependent part communicates, by means of the naso-frontal duct, either directly with the middle meatus of the nose, or indirectly with that channel through its

infundibulum. A bony septum, rarely incomplete, separates the two sinuses; it is usually mesial in position below, but it may deviate to one or other side above.

The sinuses vary considerably in their size and shape, independently of the degree of development of the glabella and superciliary ridges. According to Logan Turner, the dimensions of an average-sized sinus are: *height*, $1\frac{1}{4}$ in., from the lower end of the fronto-maxillary suture vertically upwards; *breadth*, 1 in., from the mesial septum horizontally outwards; *depth*, $\frac{3}{4}$ in., from the anterior wall backwards along the orbital roof. The sinus may exist merely as recesses limited to a small area of bone above the nose, or it may extend upwards on to the forehead for more than two inches; externally it may be limited by the bony wall of the temporal fossa, while posteriorly it may reach as far back as the optic foramen. The anterior wall is thickest, but the thickness may vary from 1 to

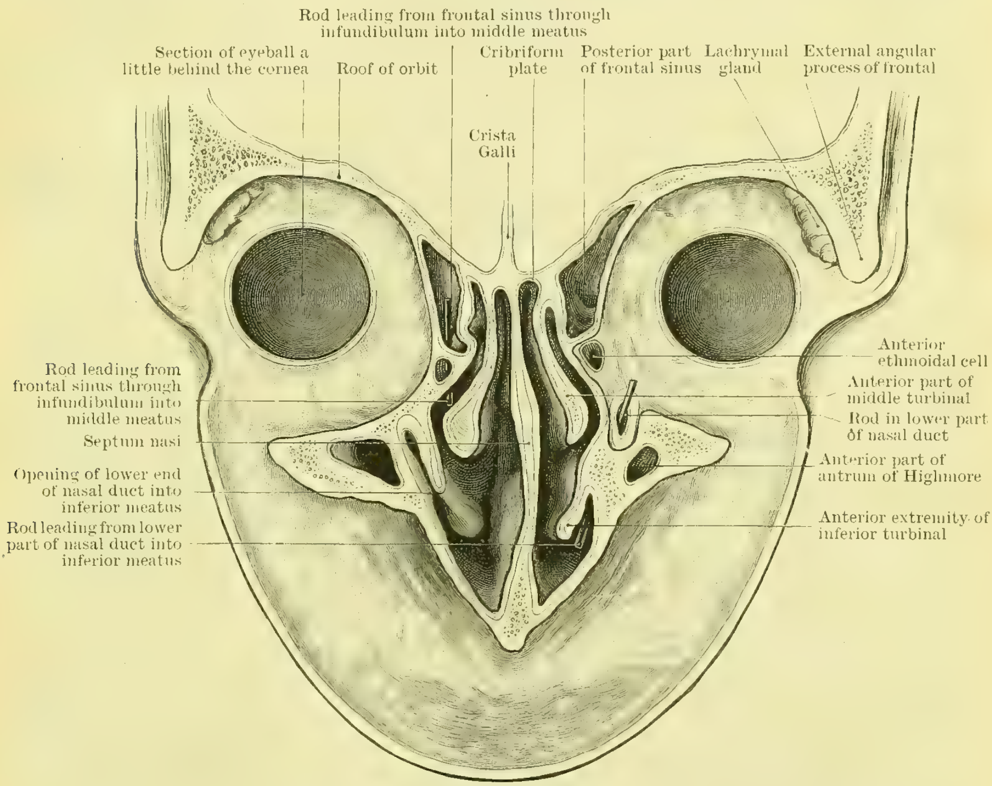

FIG. 798.—VERTICAL CORONAL SECTION THROUGH THE ANTERIOR PART OF THE ORBITAL AND NASAL CAVITIES AND THE UPPER LIP.

5 mm. The floor is the thinnest wall, hence when pus is retained within the cavity, it tends to point at the upper and inner angle of the orbit. Intracranial suppuration may arise in connexion with sinus disease by extension through the posterior wall. The muco-periosteal lining, which readily strips from the bone, is thin and pale, and provided with mucous-secreting glands.

In many individuals, by the aid of *trans-illumination*, the extent of the sinuses and the position of the intervening septum may be mapped out upon the forehead. For this purpose a small electric lamp is placed against the floor of the sinus, beneath the inner third of the supra-orbital margin. In exploring the sinus, the opening in the bone should be made close to the mesial plane, immediately above the root of the nose. In marked cases of deviation of the septum one sinus may extend so far across the mesial plane of the forehead as to reduce the other to a mere slit; in such cases the surgeon may fail to open the diseased sinus when the operation is performed through the anterior wall. The sinus frequently contains incomplete partitions, which give rise to the formation of pockets and recesses usually found towards the external angle of the sinus; when dealing with chronic suppuration of the sinuses, special attention should be paid to these recesses as well as to the backward extension of the cavity along the orbital roof. The **anterior**

ethmoidal cells are closely related to the thin inner or nasal portion of the floor of the sinus and its duct of exit; hence suppuration very frequently co-exists in both cavities. In some cases pus flows directly from the frontal sinus and infundibulum along the hiatus semilunaris into the maxillary antrum, which opens into the back part of the hiatus.

THE FACE.

The skin of the face is thin, vascular, and rich in sebaceous and sweat glands: it is intimately connected with the subcutaneous tissue, in which are imbedded the facial muscles as well as the main blood-vessels. Owing to its elasticity and to the presence of the main blood-vessels in the lax subcutaneous tissue, the face is an admirable site for plastic operations, as the flaps do not necrose in spite of considerable tension. The laxity of the tissues accounts for the marked swelling which attends œdematous and inflammatory conditions about the face. Whenever possible, incisions should be made along the line of the natural furrows and creases of the skin, so as to render the resulting cicatrix less noticeable.

The bony landmarks of the face which may be readily palpated are: the **superciliary ridges** and the **glabella,** the **nasion** (fronto-nasal junction), the **bridge of the nose,** the **osseous anterior nares** and the **nasal spine**, the **supra- and infra-orbital margins,** the **external** and **internal angular processes,** the anterior part of the **temporal crest**, the **malar bone**, the **zygomatic arch,** and the region of the **canine fossa** of the upper jaw.

Immediately below the root of the zygoma, and in front of the upper part of the tragus, is the **condyle of the jaw.** By pressing with the point of the finger upon the condyle while the mouth is being widely opened, the bone will be felt to glide forward, while the finger sinks deeply into the hollow corresponding to the **glenoid cavity.** The close relation of the first part of the **internal maxillary artery** to the inner aspect of the neck of the jaw must be kept in mind in operations calling for disarticulation or excision of the condyle. The ascending **ramus of the jaw** is sandwiched between the masseter and the pterygoid muscles, and can be removed without opening into the mouth. Passing downwards from the condyle, one can palpate the anterior and posterior borders of the ascending ramus and the **angle** and **body of the mandible.** The anterior border of the **coronoid process** is felt in front of the upper part of the anterior border of the masseter, immediately below the anterior part of the zygomatic arch.

The pulsation of the **facial artery** may be felt as the vessel crosses the lower margin of the mandible at the anterior border of the masseter, 1 in. in front of the angle of the jaw. To map out the course of the artery upon the face, draw a line from this point to a point $\frac{1}{2}$ in. external to the angle of the mouth, and thence to a point a little behind the ala nasi and along the side of the nose to the inner angle of the orbit. The **facial vein** lies behind the facial artery, and takes a straighter course from the inner canthus to the anterior inferior angle of the masseter. The vessel is devoid of valves, hence infective phlebitis and thrombosis are liable to spread along it to the cavernous sinus by way of the ophthalmic and pterygoid veins.

A line projected downwards from the supra-orbital notch (junction of inner and middle thirds of the supra-orbital margin) to the lower border of the mandible opposite the interval between the two lower bicuspid teeth, will cross the **infra-orbital** and **mental foramina**, the former $\frac{1}{4}$ in. below the infra-orbital margin, the latter midway between the upper and lower borders of the lower jaw. In performing the operation of neurectomy for the relief of trigeminal neuralgia, these foramina furnish the guides to the correspondingly-named branches of the fifth nerve. It should be remembered that the nerves in question, after emerging from their respective foramina, lie, in the first instance, beneath the facial muscles. The supra-orbital and infra-orbital nerves are not infrequently represented each by two branches, one of which passes through an accessory foramen situated external to the normal opening. Neurectomy of the **inferior dental nerve** is performed by trephining the ascending ramus of the jaw midway between its anterior and posterior borders, on a level with the crown of the last molar tooth, the nerve being

reached as it enters the inferior dental canal; the **lingual nerve**, which lies a little anterior to the inferior dental, can be exposed through the same opening.

The **facial nerve**, after emerging from the stylo-mastoid foramen, is imbedded in the parotid gland where it is superficial to the external carotid artery; the nerve can be rolled under the finger as it crosses the posterior border of the ascending ramus of the jaw at the level of the lower margin of the tragus; incisions continued along the ramus above this point should be only skin deep if the nerve is to be avoided. To expose the trunk of the nerve an incision is made from the anterior border of the mastoid process to the angle of the jaw. Incisions upon the cheek should, whenever possible, be planned so as to run parallel with the branches of the nerve; these radiate from the lower end of the tragus. The nerve may be paralysed by wounds of the cheek and by malignant tumours of the parotid, as also by intracranial and middle-ear lesions.

The **parotid gland** is surrounded by a fascial envelope, the strongest portion of which is continued from the deep cervical fascia over its superficial aspect to become attached to the zygoma (Fig. 647); hence abscesses in the parotid tend to burrow deeply towards the pterygo-maxillary space and the upper part of the pharynx; the pus should therefore be evacuated by Hilton's method, through an early incision over the angle of the jaw. A study of the relations of the gland explains the surgical difficulties which attend its complete removal.

The **parotid duct** can be rolled beneath the finger as it crosses the masseter, rather less than a finger's breadth below the zygoma. After winding over the anterior border of the muscle it soon pierces the buccinator, and opens into the mouth opposite to the second molar tooth of the upper jaw. The level and direction of the duct may be marked out upon the surface by drawing a line from the lower margin of the concha to a point midway between the ala nasi and the angle of the mouth.

Superficial to the parotid and a little in front of the tragus is the **pre-auricular lymphatic gland**, which is frequently found to be inflamed in children suffering from eczematous conditions of the eyelids, face, scalp, and external ear. In opening an abscess connected with this gland care must be taken to make the incision as low down as possible, so as to avoid the parotid duct.

Eyelids.—The skin of the **eyelids**, more especially of the upper, is very thin and connected with the orbicularis muscle by delicate and lax subcutaneous tissue destitute of fat; hence the marked swelling which occurs in a "black eye" and in œdema of the lids. Along the anterior edge of the free margins of the lids are the eyelashes and the orifices of the sebaceous glands, suppurative inflammation of which gives rise to a "*stye*"; along the sharp posterior edge of the free margins are the minute orifices of the **Meibomian glands**. These glands, imbedded in the deep surface of the tarsal plates, are seen through the palpebral conjunctiva as a row of parallel, yellowish, granular-looking streaks. From the deep position of the glands it follows that the skin over a Meibomian cyst is freely movable, and that to reach the cyst an incision should be made through the conjunctival surface of the lid.

The **palpebral conjunctiva** is closely adherent to the ocular surface of the tarsal plates; at the fornix it is loose and contains small lymphoid follicles, which become hypertrophied in the condition known as granular conjunctivitis. The **ocular conjunctiva** is thin, transparent, and loosely attached to the sclerotic, so that in operating upon the eye a fold of the membrane can be picked up with forceps to steady the eyeball.

In inflammatory affections of the eye the state of those vessels which are visible gives important information as to the seat of the mischief. For example, in inflammation of the *conjunctiva* the posterior conjunctival vessels (derived from the palpebral arteries), scarcely visible normally, appear as a close network which fades away towards the corneal margin; these vessels move freely with the conjunctiva, and do not disappear under pressure. In superficial inflammations of the *cornea* the anterior conjunctival vessels (the most superficial of the terminal branches of the anterior ciliary arteries) are seen to spread in a freely branching manner into its superficial layers. In *iritis* and deep inflammations of the cornea there is a pink circumcorneal zone of vascular dilatation consisting

of delicate straight vessels which disappear under pressure and do not move with the conjunctiva; they are the subconjunctival (episclerotic) terminations of the anterior ciliary arteries; in health they are invisible.

Lachrymal Apparatus.—The **lachrymal gland**, situated behind the outer part of the supra-orbital margin, cannot be felt unless enlarged. By everting and raising the upper eyelid, the accessory (palpebral) portion of the gland is seen to project beneath the outer third of the fornix, in which situation also the minute orifices of the lachrymal ducts may be detected. By gently drawing downwards the lower lid, the small **punctum lachrymale** is seen situated upon a slight papillary elevation of its margin about 4 mm. from the inner canthus; the corresponding orifice of the upper lid is placed a little nearer the canthus. Normally the puncta are directed towards, and accurately applied to, the ocular conjunctiva immediately external to the caruncle. By drawing the lids outwards the **internal palpebral ligament** is put upon the stretch, and can be felt as a narrow tense band passing transversely inwards to be attached to the nasal process of the superior maxilla. The ligament is a guide to the position of the **lachrymal sac,** which it crosses a little above its centre. Continuous with the lower end of the lachrymal sac is the **nasal duct**, which passes downwards and slightly backwards and outwards, to open into the inferior meatus of the nose, under cover of the anterior end of the inferior turbinal. The lachrymal sac and duct each measure about ½ in. in length; the latter is slightly contracted at its commencement and termination, and it is in these situations that pathological strictures of the duct are commonest. Spontaneous rupture of an abscess of the lachrymal sac almost invariably occurs just below the tendo palpebrarum; it is in this situation that the abscess should be opened, the incision being made a little external to the angular termination of the facial artery.

The **canaliculi lachrymales,** which convey the tears from the puncta to the lachrymal sac, run for the first 1-2 mm. almost vertically to the free margins of the lids, and thence parallel to them. Between the canaliculi is the **lachrymal caruncle.** In the various morbid conditions which give rise either to misdirection of the puncta or to stricture at any part of the lachrymal drainage apparatus, overflow of the tears (*epiphora*) is the chief symptom. In passing a probe along a canaliculus the instrument, in consequence of the bend upon the duct, is passed at first vertically to the margin of the lid, and afterwards parallel to it, until the point is felt to strike against the inner wall of the lachrymal sac; to pass the instrument onwards along the nasal duct the handle is rotated forwards and upwards through a quarter of a circle, and then pushed gently downwards and slightly backwards and outwards into the inferior meatus of the nose.

The **tarsal "cartilages"** are attached to the periosteum of the orbital margins by the **orbito-tarsal ligaments** which shut off the communication between the subcutaneous tissue of the eyelids and the fatty tissue of the orbital cavity. In fracture of the anterior fossa of the base of the skull involving the orbital plate, the blood extends forwards between the periosteum and the musculo-fascial envelope of the orbit and appears under the conjunctiva.

To obtain free access to the cavity of the orbit, the surgeon first enlarges the palpebral fissure by making a horizontal incision from the outer canthus to the outer margin of the orbit, and then, after everting the eyelid, divides the conjunctiva along the fornix of the upper or lower lid, or of both, as may be desired.

Nose.—To examine the anterior nares (*anterior rhinoscopy*) a strong light is reflected into the nostril which is dilated by means of a nasal speculum. The **anterior extremity of the inferior turbinal** appears as a rounded body projecting from the outer wall of the nose; in turgescence of its erectile tissue it is liable to come in contact with the nasal septum and so occlude the nostril. The **inferior meatus,** situated between the inferior turbinated body and the floor of the nasal fossa, is brought into view by tilting forwards the head. The **lower aperture of the nasal duct** is concealed from view by the anterior part of the inferior turbinal. The **floor** of the nose is horizontal and placed on a slightly lower level than the anterior nares. The **septum**, generally more or less deviated to one or other side, is seen when the head is slightly rotated away from the side to be examined. The

anterior part of the middle turbinal is seen when the patient's head is thrown well back; between it and the septum is a slit-like interval (*olfactory cleft*). By rotating the patient's head towards the corresponding shoulder the **anterior part of the middle meatus** is brought into view; pus in this situation may originate from the frontal, the anterior ethmoidal, or the maxillary sinuses, all of which open into the **hiatus semilunaris** of the middle meatus (Fig. 490).

To make a satisfactory *digital exploration* of the anterior part of the nasal cavities, it is necessary to divide the columella and the cartilaginous septum with a strong pair of scissors, one blade being introduced into each nostril (Kocher); blood spurts from the small arteries of the septum, but the bleeding soon ceases. When these vessels, which are derived from the superior coronary arteries, are the source of the hæmorrhage in epistaxis, the bleeding can be arrested either by compressing the coronary arteries, by plugging the anterior nares, or by grasping the cartilaginous part of the nose firmly between the finger and thumb.

The **maxillary sinus** or **antrum of Highmore**, situated in the upper jaw, is a pyramidal cavity with its base formed by the outer wall of the nose and its apex directed towards the malar bone (Fig. 121). The cavity is lined by a thin mucoperiosteal membrane, easily separable from the bone; in the mucous layer are numerous mucous glands from which cysts may develop. The floor of the antrum, which is normally on a level with the floor of the nose, is separated from the roots of the bicuspid and molar teeth by a plate of bone of varying thickness. When this plate is thin and devoid of spongiosa, the floor of the antrum sinks below the level of the floor of the nose, and suppuration at the roots of one of the teeth above mentioned is in these circumstances very liable to extend to the antrum. In an antrum of average dimensions the line of union of the nasal and facial walls of the cavity corresponds externally to the outer edge of the canine ridge (Logan Turner). The *antral orifice* is situated at the highest part of the antrum, and is therefore unfavourably placed for natural drainage; it opens into the posterior and lower part of the infundibulum which, in its turn, communicates with the middle meatus of the nose through the *hiatus semilunaris*. In old age there is frequently a second communication between the antrum and middle meatus, the opening being situated behind and below the normal orifice; when this accessory osteum exists pus from the antrum may drain backwards into the naso-pharynx (Logan Turner). In *empyema of the antrum* the opening to evacuate and drain the cavity may be made (1) through the alveolus of the second bicuspid or of the first or second molar tooth, the first molar being the site of election; (2) through the canine fossa, external to the prominence caused by the root of the canine tooth; or (3) through the outer wall of the inferior meatus of the nose.

Lips.—In compressing the **coronary arteries**, it must be remembered that they run beneath the mucous surface of the lips a short distance from their free margins. The lips are abundantly supplied with **mucous glands** which can be felt immediately beneath the mucous membrane nearer their attached than their free borders; the glands are a frequent source of mucous cysts; occasionally they are enlarged congenitally, giving rise to one form of hypertrophy of the lip.

Hare-lip is due to failure of the union of the internal nasal subdivision of the fronto-nasal process with the maxillary process. The deformity is spoken of as complete or incomplete according as the cleft extends into the nostril or merely involves a portion of the lip. The fissure may involve the lip only, or it may include the alveolar process of the jaw; in the latter case the cleft may or may not be associated with a cleft of the palate. Lastly, the hare-lip may be single or double, according as the deficiency has occurred on one (usually the left) or both sides; in the latter case the central portion of the lip and the premaxillæ project more or less markedly from the nasal septum.

Teeth.—The **milk teeth** begin to appear from the sixth to the eighth month, the first to emerge being the lower central incisors. The first dentition is completed about the thirtieth month. Delayed dentition is generally due to rickets. Of the **permanent set** the first to erupt are the first molars, which appear at the end of the sixth or seventh year; the third molars (wisdom teeth), the last to appear, may erupt any time between the eighteenth and the twenty-fifth year, or even later.

As the permanent teeth push their way towards the surface, absorption of the roots of the first set takes place, which either fall out of their own accord or are easily removed. Loss of the permanent teeth is followed by absorption of the alveolar margin of the jaw. The tooth sockets are lined by a thin periosteum, which is anatomically continuous with the pulp tissue of the teeth on the one hand and the dense fibrous tissue of the deep layer of the gum on the other.

The upper incisors and canines and the lower bicuspids have *cylindrical* roots, hence in extracting these teeth they should be first loosened by a slight rotatory movement; the roots of the lower incisors and canines and of the upper bicuspids are *flattened*, so that they must be loosened by a lateral movement. The roots of the wisdom teeth are *convergent*, generally welded together and curved backwards, especially in the lower jaw. The first and second upper molars have three roots which are often *divergent* (Figs. 650 and 651).

Tongue.—For practical purposes, as well as on developmental and structural grounds, it is convenient to divide the tongue into an anterior two-thirds—the **oro-glossus**, and a posterior third—the **pharyngo-glossus** (Wingrave), Fig. 640. At the junction of the two portions, immediately behind the median circumvallate papilla, is the **foramen cæcum**, which represents the remains of the upper or pharyngeal extremity of the **thyro-glossal duct**. *Congenital cysts* and *fistulæ* which develop from unobliterated portions of this duct are always mesial; those arising from the upper or lingual portion of the duct are situated between the genio-hyo-glossi, whereas those developed from the lower or thyroid portion are situated below the hyoid bone.

The mucous membrane covering the pharyngo-glossus is much more sensitive than that covering the oro-glossus, hence in using a tongue depressor the instrument should, except under special circumstances, rest only upon the latter region, otherwise a reflex arching of the tongue will be set up, which prevents the operator from obtaining a satisfactory view of the throat. Scattered over the pharyngo-glossus are clusters of **lymphoid follicles** (lingual tonsils), which appear on the surface as a number of nodular umbilicated elevations provided with little crypts into which mucous glands open (Fig. 641). The lingual tonsils are liable to chronic inflammation and hypertrophy, conditions which are often accompanied by a varicose condition of the veins which lie immediately beneath the mucous membrane containing the palato-glossus muscle. To obtain a satisfactory view of the lingual tonsils in the living subject the laryngoscopic mirror must be employed.

The **muscular bundles** of the tongue are separated by a quantity of loose connective tissue, rich in blood-vessels and lymphatics (Fig. 644): hence acute inflammatory œdema of the substance of the tongue may be attended with a degree of swelling sufficient to obstruct the respiratory passage.

The main **blood-vessels** of the tongue run from behind forwards, nearer its under than its upper surface; incisions into the substance of the tongue to reduce swelling and tension should, therefore, be made longitudinally upon the dorsum. Bleeding from the lingual artery, divided in the substance of the tongue, is temporarily arrested by passing the finger behind the base of the tongue and hooking it well forward, so as to compress the vessel against the inner surface of the lower jaw. On account of the very slender anastomosis between the vessels of the two halves of the tongue scarcely any bleeding occurs when the organ is split mesially.

Between the tongue and the inner surface of the gums is the **alveolo-glossal sulcus**, crossed in the middle line by the **frenum linguæ**, which passes upwards to the under surface of the tongue (Fig. 643). Immediately on either side of the lower part of the frenum is the **orifice of Wharton's duct**. A little external to the frenum the **ranine veins** are seen lying immediately under the thin mucous membrane; to the outer side of the veins are the ranine arteries and the lingual nerves, both of which lie deeper than the veins, and are therefore not visible.

The mucous membrane at the anterior part of the floor of the alveolo-glossal sulcus is thrown into a slight elevation, which overlies, and is caused by, the **sublingual salivary gland**. The duct of the submaxillary gland (Wharton's duct) and the lingual nerve lie beneath and to the inner side of the sublingual gland.

In dividing a shortened frenum for "tongue-tie" the ranine vessels and the orifices of Wharton's ducts must be avoided. Behind the frenum linguæ are the anterior borders of the **genio-hyo-glossi**, which descend to the upper genial tubercles. In operations necessitating the removal of the region of the symphysis of the jaw, or the separation of the origins of the genio-hyo-glossi, the tongue must be kept forward, otherwise the patient will be suffocated by the organ falling backwards over the entrance to the larynx. In removing a small salivary calculus from the floor of the mouth the calculus should be fixed with the finger against the inner surface of the jaw before cutting down upon it.

When the teeth are clenched the vestibule of the mouth communicates behind the last molars with the oral cavity proper through an opening which barely admits a medium-sized catheter. Hence, when the jaws cannot be separated it is generally necessary to feed the patient through a tube passed along the floor of the nose.

By opening the mouth widely and taking a deep inspiration, the soft palate is elevated, and the anterior and posterior pillars of the fauces are rendered prominent (Fig. 638). The **anterior pillars** are seen to spring from the anterior surface of the soft palate, close to the base of the uvula, and to arch downwards and outwards in front of the tonsils to end at the posterior extremity of the lateral border of the tongue. The **posterior pillars** are really the continuation of the lower free border of the soft palate downwards behind the tonsils to become attached to, and lost upon, the postero-lateral wall of the pharynx. Together with the lower edge of the soft palate and the base of the tongue they bound a hemispherical opening (**isthmus faucium**), through which is visible the oral portion of the mucous membrane covering the posterior wall of the pharynx.

The **faucial tonsils** lie one on each side of the isthmus, between the anterior and posterior pillars of the fauces; they are situated opposite the angle of the jaw, but they cannot be felt from the outside. Each tonsil is covered on its free surface by mucous membrane upon which are seen the orifices of the tonsillar crypts; the outer or deep surface is covered by a layer of fibrous tissue which forms an imperfect capsule to the organ. According to Merkel, the internal carotid artery is situated 1·5 cm. behind the outer margin of the tonsil, which is separated from the superior constrictor by a quantity of loose cellular tissue and fat, so that the gland can be grasped with a volsellum and pulled forward without dragging the vessel with it. The tonsil receives its *blood-supply* mainly from a small vessel derived from the anterior palatine artery; when this branch is larger than usual and adherent to the capsule of the tonsil the bleeding which attends the operation of removal of the tonsils may be considerable. The hæmorrhage can be arrested by pressing the bleeding point outwards against the internal pterygoid and the ramus of the jaw. If the bleeding be from a spurting vessel of larger size, its source, according to Merkel, is probably the *facial artery*, which has been wounded as it arches upwards beneath the digastric and stylo-hyoid muscles to within a short distance from the outer surface of the tonsil. In children and adolescents the tonsils are frequently hypertrophied; the enlargement may be either general, more towards the middle line, downwards along the pharynx, or upwards behind the soft palate; to expose and thoroughly remove the last-mentioned variety of enlargement the upper part of the anterior pillar of the fauces must be divided.

The mucous membrane and the periosteum of the **hard palate** are so closely united as to form practically one membrane. The **posterior palatine arteries**, after leaving the posterior palatine foramina, run forward in shallow grooves in the hard palate, close to its alveolar margin. In the operation for cleft palate (*staphylorraphy*), in order to secure nourishment for the muco-periosteal flaps, the lateral incisions should be made *external* to these vessels.

Secondary hæmorrhage after the operation for cleft palate is treated by plugging the **posterior palatine foramen**, which lies a little internal to the last molar tooth about $\frac{1}{3}$ in. in front of the hamular process, which can be felt at the upper extremity of the fold of mucous membrane containing the pterygo-maxillary ligament. In the closure of a wide cleft of the soft palate the tension of the **tensor palati muscle** is got rid of

by chipping off the **hamular process** with a small chisel introduced at the posterior extremity of the lateral relief incisions.

Naso-pharynx.—To explore the upper or nasal division of the pharynx the finger should be hooked upwards behind the soft palate. *Anteriorly*, the finger readily detects the sharp posterior border of the vomer, the posterior nares, and the posterior extremity of the middle and inferior turbinals. The *roof* of the space is formed by the basilar process of the occipital bone, while upon the *posterior wall* is a transverse bony ridge caused by the projection of the anterior arch of the atlas. Upon the *lateral walls* of the naso-pharynx are the openings of the **Eustachian tubes**, situated ½ in. behind the posterior extremities of the inferior turbinals (Fig. 639). The orifices, bounded superiorly and posteriorly by a prominent margin, are directed downwards and forwards, and, therefore, in a direction favourable to the passage of the Eustachian catheter. Behind the prominent posterior margin of the orifice is a lateral recess of the pharynx known as the **fossa of Rosenmüller**, in which the point of the Eustachian catheter is apt to become engaged. Upon the roof and posterior wall of the pharynx, down to the level of the anterior arch of the atlas, and extending laterally as far as the Eustachian orifices, is a collection of adenoid tissue, the **pharyngeal tonsil**. Hypertrophy of this tissue constitutes the condition known as "*adenoids*," the harmful effects of which are due to their interference with nasal respiration. Upon the centre of the pharyngeal tonsil is an orifice leading into a small recess into which numerous mucous glands open. The structures felt in the post-nasal space may be rendered visible by reflecting the light upon a small mirror placed immediately behind and below the soft palate (*posterior rhinoscopy*). The lower part of the inferior turbinal is obscured from view by the bulging of the upper surface of the soft palate.

In *plugging the posterior nares*, it is important to remember that these openings measure nearly one inch in the vertical and half an inch in the transverse direction. In the child, owing to the small size of the face, the vertical diameter of the naso-pharynx is relatively much smaller than in the adult.

The **lymphatics** of the pharynx join the upper deep cervical glands, one of which lies internal to the carotid vessel between the lateral recess of the pharynx and the prevertebral fascia. In children suppuration originating in this gland is the commonest cause of a retro-pharyngeal abscess.

In the *adult* the four upper cervical vertebræ can be explored from the mouth, while in the *child* the finger can also reach as far down as the sixth vertebra and the back of the cricoid cartilage.

THE NECK.

The general envelope of **deep cervical fascia,** along with the processes and partitions which proceed from its deep surface, subdivides the neck into compartments which limit and determine the spread of pus. The most important compartment is the **central** or **visceral compartment**, bounded *anteriorly* by the pretracheal fascia, *posteriorly* by the prevertebral fascia, and *laterally* by the fascia forming the vascular compartment. Posteriorly, this compartment extends from the base of the skull downwards into the posterior mediastinum; anteriorly, it extends from the hyoid bone into the anterior part of the superior mediastinum. *Abscesses* in the visceral compartment are either secondary to disease of the organs it contains, or the result of a primary suppurative cellulitis. A tubercular abscess originating in one of the retropharyngeal lymphatic glands lies *in front of* the prevertebral fascia, and points towards the posterior wall of the pharynx; abscesses secondary to disease of the cervical vertebræ lie *behind* the prevertebral fascia, and spread laterally behind the vascular compartment; they point behind the sterno-mastoid, and should be opened through an incision at the posterior border of the muscle, the surgeon keeping to the anterior aspect of the transverse processes in order to avoid the structures in the vascular compartment (Chiene).

In front of the visceral compartment is a **small muscular compartment** containing the depressor muscles of the hyoid bone; anterior to it again, in the region of the supra-sternal notch, is the small **supra-sternal compartment**, containing the lower

part of the anterior jugular veins along with their transverse communicating branch, a little fat, and one or two lymphatic glands.

The **vascular compartment,** triangular in section, is bounded *anteriorly* by the general fascial envelope, which splits at the omo-hyoid to enclose the depressors of the hyoid bone; *posteriorly* by the prevertebral fascia; *internally* by the visceral compartment; *externally* by the meeting of the prevertebral fascia and the posterior layer of the sterno-mastoid sheath. This compartment contains the carotid vessels, and the internal jugular vein, and the following nerves, viz.: the vagus, the first part of the hypoglossal, the descendens hypoglossi, and the upper part of the spinal accessory. The **carotid chain of lymphatic glands** lies in the cellular tissue which connects the various structures in the compartment; normally they may be readily separated from the sheath of the internal jugular vein, to which,

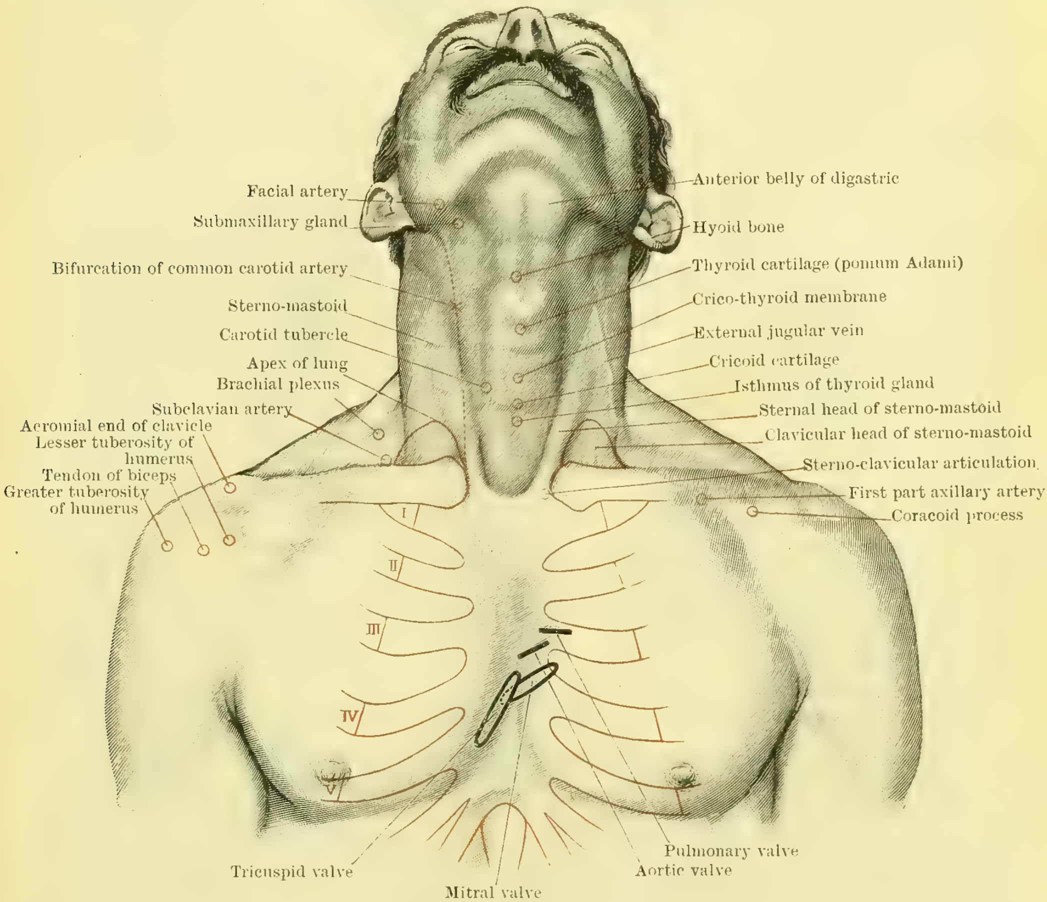

FIG. 799.—ANTERIOR ASPECT OF NECK AND SHOULDERS.

however, they become adherent when inflamed. A glandular abscess in this compartment usually points upon the surface, adhesions being formed, first, between the gland and the fascia, and, subsequently, between the latter and the cutaneous structures. In diffuse suppurative cellulitis of this compartment the pus burrows towards the root of the neck, and may reach either the mediastinum or the axilla.

Middle Line of the Neck.—The body of the **hyoid bone** divides the middle line of the neck into **supra- and infra-hyoid portions.** Above the hyoid bone is the **submental triangle**, with its apex at the lower border of the symphysis menti and its sides formed by the anterior bellies of the digastrics. In the floor of the triangle are the anterior portions of the mylo-hyoid muscles, separated by the median raphe. The most important structures in the triangle are the **supra-hyoid lymphatic glands**, which can usually be felt a little above the body of the hyoid bone. They are a frequent seat of abscess secondary to impetigo of the lower lip

and chin. About 1 in. below the hyoid bone is the **pomum Adami,** more prominent in the male than in the female. On either side of the pomum Adami are the alæ of the thyroid cartilage, while between the latter and the hyoid bone is the **thyro-hyoid membrane.** In the operation of *sub-hyoid pharyngotomy* the epiglottis and the superior opening of the larynx are reached by passing through the anterior wall of the pharynx at the level of the thyro-hyoid membrane. The structures divided from without inwards are: the integuments, the sterno-hyoid, omo-hyoid, and thyro-hyoid muscles, the middle portion of the thyro-hyoid membrane, along with a layer of fat between it and the lower part of the epiglottis, and, finally, the glosso-epiglottidean ligament and fold of mucous membrane. The incision must not be extended too far on either side of the mesial plane for fear of wounding the **superior laryngeal vessels** and **nerve** which pierce the thin lateral portions of the thyro-hyoid membrane.

The wound in suicidal *cut-throat* is generally at this level. The more important structures which are usually divided are: more or less of the left sterno-mastoid muscle, the superior thyroid vessels, the thyro-hyoid membrane, the base of the epiglottis, and, less frequently, the carotid vessels, the internal jugular vein, and the superior laryngeal nerve. When the wound is above the hyoid bone, the lingual and facial vessels and the muscles of the tongue are the more important structures injured.

At the level of the middle of the anterior border of the thyroid cartilage is the **rima glottidis.** A little more than an inch below the pomum Adami is the anterior arch of the **cricoid cartilage,** which may be readily felt, and, when the neck is extended, often seen; it lies a little below a point midway between the lower margin of the chin and the upper border of the sternum. Above the cricoid is the **crico-thyroid membrane**: in the operation of laryngotomy only the middle portion of the membrane is divided, in order to avoid injury to the crico-thyroid muscles. The small crico-thyroid branch of the superior thyroid artery lies close to the lower border of the thyroid cartilage. Below the cricoid cartilage is the **trachea,** which recedes as it descends, so that it lies $1\frac{1}{2}$ in. from the surface at the level of the upper border of the sternum. The **isthmus** of the **thyroid gland** lies in front of the second, third, and fourth rings of the trachea (Fig. 789); not infrequently, however, it reaches up to the cricoid. Immediately in front of the trachea, below the isthmus of the thyroid, is the pretracheal fat, containing one or two **lymphatic glands** and the **inferior thyroid veins,** each represented by one or more branches which converge as they descend. In the adult the **innominate artery** crosses the front of the trachea at the level of the upper border of the sternum: in the child, however, it not infrequently crosses half an inch higher, a relation which must be remembered in performing the operation of low tracheotomy.

In the operation of **high tracheotomy** the upper three rings of the trachea are divided. The incision, which should be mesial, divides the integuments, the tributaries of the anterior jugular veins, the general envelope of deep cervical fascia, and, after passing between the depressor muscles of the hyoid bone, the pretracheal fascia, which descends from the cricoid to enclose the isthmus of the thyroid gland. By dividing this fascia transversely below the cricoid, the isthmus may be pulled downwards and the upper rings of the trachea exposed. In some cases it is necessary either to divide the isthmus or to extend the incision upwards through the cricoid cartilage. In opening the trachea, the edge of the knife should be directed upwards so as to avoid injuring the vessels at the upper border of the isthmus. The anterior jugular veins are in danger of being wounded if the skin incision is not strictly mesial. In low tracheotomy the trachea below the isthmus is opened; it is a more troublesome operation on account of the depth of the trachea and the presence in front of it of the large inferior thyroid veins and of the transverse anterior jugular vein. In children the difficulty is increased by the higher position of the innominate artery and left innominate vein, by the presence of the thymus gland, and by the shortness of the neck.

Triangles of the Neck.—The lateral aspect of the neck may be divided into an **anterior** and a **posterior triangle** by the sterno-mastoid muscle; the former is further subdivided into *digastric, carotid,* and *muscular triangles* by the digastric and omo-hyoid muscles. The posterior triangle is subdivided into *occipital* and *clavicular portions* by the posterior belly of the omo-hyoid.

The **sterno-mastoid muscle** forms one of the most important superficial landmarks of the neck. The anterior border of the muscle, the more distinct of the

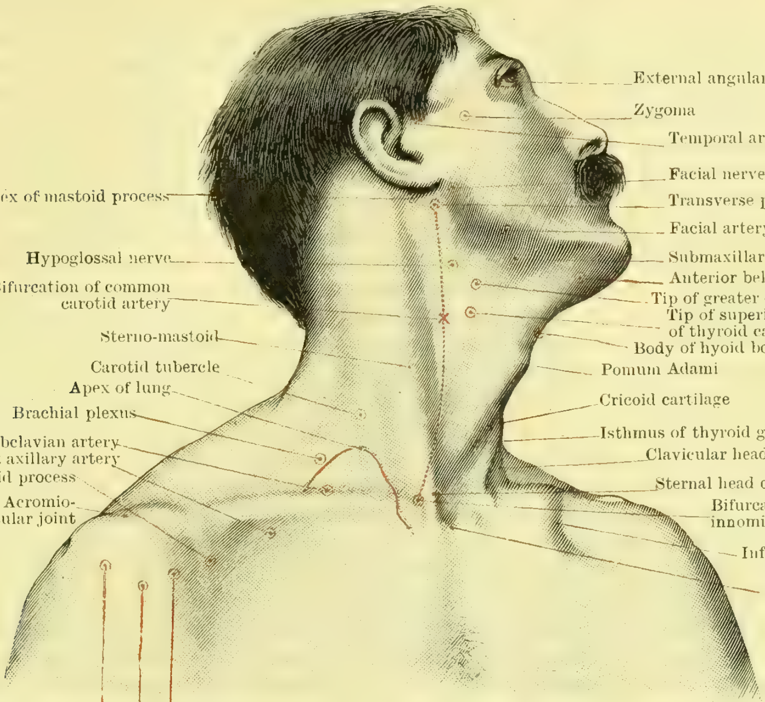

FIG. 800.—LATERAL ASPECT OF NECK.

two, may be felt along its whole extent. Between the prominent sternal origin and the broad ribbon-like clavicular origin is a slight triangular depression which overlies the lower part of the internal jugular vein.

Digastric Triangle.—This triangle is subdivided into an anterior or submaxillary portion and a posterior or parotid portion by the stylo-maxillary ligament. In the anterior portion is the **submaxillary gland**, which extends from the posterior half of the lower border of the mandible to the great cornu of the hyoid bone. The **facial vein** passes downwards and backwards superficial to the gland, while the **facial artery**, imbedded in its deep surface, arches upwards under cover of the angle of the jaw, where, according to Merkel, it approaches the tonsil, being separated from it, however, by the superior constrictor of the pharynx. The **lingual artery** may be ligatured in the digastric triangle, where it lies behind the hyo-glossus a little above the great cornu of the hyoid bone; the superficial guides to the vessel are the lower border of the submaxillary gland, and the hypoglossal nerve and lingual vein, which lie upon the hyo-glossus, the latter being recognised by the vertical direction of its fibres. The *floor* of the digastric triangle is formed, from before backwards, by the mylo-hyoid, hyo-glossus, and superior constrictor of the pharynx. The **lymphatic glands** of this space receive their lymphatics from the face and mouth, including the tongue and teeth. Primary suppurative cellulitis of the connective tissue of this space is called *angina Ludovici*.

Carotid Triangle.—The central landmark of this triangle is the **great cornu** of the **hyoid bone**, the tip of which, when the fascia is relaxed, may be readily felt immediately in front of the anterior border of the sterno-mastoid, at a point corresponding to the centre of a line drawn from the tip of the mastoid process to the pomum Adami. The deep cervical fascia holds the upper part of the sterno-mastoid forwards towards the angle of the jaw, so that, with the fascia undivided, the anterior border of the sterno-mastoid overlaps the internal jugular vein and the bifurcation of the common carotid artery.

The **course of the carotid vessels** is indicated upon the surface by a line extending from the upper end of the sterno-clavicular articulation to a point midway between the angle of the jaw and the tip of the mastoid process; a point upon this line, at the level of the upper border of the thyroid cartilage, overlies the **bifurcation of the common carotid**. The **anterior belly** of the **omo-hyoid** crosses the common carotid at the level of the cricoid cartilage. The pulsations of the carotid vessels may be felt in the hollow between the larynx and the anterior border of the sterno-mastoid. In the carotid triangle the **external carotid** lies internal and anterior to the internal carotid. The seat of election for *ligation of the external carotid* is between its superior thyroid and lingual branches, a finger's breadth below the tip of the great cornu of the hyoid bone; the difficulty in the operation is due to the plexus of veins (formed by the common facial, lingual, and superior thyroid veins) which overlies the artery. The lingual and facial arteries frequently arise from a common trunk which must not be mistaken for the external carotid. The **superior thyroid artery** arises opposite the upper cornu of the thyroid cartilage, which may be distinctly felt 1 in. below the tip of the great cornu of the hyoid bone. The vessel and its companion vein are common sources of hæmorrhage in cut-throat. The guide to the **lingual artery**, in the carotid triangle, is the tip of the great cornu of the hyoid bone, above which it forms an arch, crossed by the hypoglossal nerve. The vessel enters the digastric triangle by passing beneath the tendons of the stylo-hyoid and digastric muscles. When ligation of the artery is called for, it is, as a rule, preferable to secure it in the carotid rather than the digastric triangle.

From a surgical point of view the **internal jugular vein** is the most important structure in the anterior triangle. In the carotid division of the triangle it overlaps the carotid vessels, and its sheath lies close beneath the general envelope of deep cervical fascia. About the level of the hyoid bone it receives the large **common facial vein**, and it is the glands in the neighbourhood of those which overlie the junction of this vein with the internal jugular that are most frequently the seat of tubercular disease, because they receive such a large number of the lymphatics of the head, both superficial and deep.

The **hypoglossal nerve** curves forwards across the carotid vessels at the level of the lower border of the posterior belly of the digastric. The **vagus nerve** descends vertically behind and between the carotid vessels and the internal jugular vein; care must be taken not to include it when ligaturing the common carotid or internal jugular. Surgically, the **spinal accessory** is the most important nerve in the anterior triangle; it enters the substance of the sterno-mastoid muscle $1\frac{1}{2}$ in. below the tip of the mastoid process. A portion of the nerve is resected in the treatment of spasmodic wry-neck, and it is almost always exposed in the removal of the upper carotid group of deep cervical glands. The course of the nerve may be mapped out upon the surface by drawing a line from a point midway between the tip of the mastoid process and the angle of the jaw to the middle of the posterior border of the sterno-mastoid muscle, and thence across the posterior triangle to the anterior border of the trapezius, beneath which it passes at the level of the seventh cervical spine. The deeper guides to the nerve are the posterior belly of the digastric, the internal jugular vein, and the **transverse process of the atlas**, which is felt as a distinct bony landmark midway between the tip of the mastoid and the angle of the jaw. The **cervical sympathetic** lies in the posterior wall of the vascular compartment of the neck, and may be reached by an incision along the posterior border of the sterno-mastoid: the anterior surfaces of the roots of the transverse processes of the vertebræ are the deep guides to the nerve. The **cervical plexus**, which lies behind the upper half of the sterno-mastoid upon the levator anguli scapulæ and scalenus medius muscles, may be exposed through an incision along the posterior border of the upper half of the sterno-mastoid muscle. The **phrenic nerve**, the most important branch of the cervical plexus, arises one inch above the carotid tubercle and descends almost vertically upon the scalenus anticus; it is overlapped by the outer margin of the internal jugular vein.

The **muscular** or **lower carotid triangle** is an important triangular intermuscular space bounded by the anterior border of the sterno-mastoid, the anterior

belly of the omo-hyoid and the sterno-hyoid. By making an incision along the left anterior border of the sterno-mastoid muscle, and passing through this triangle, the surgeon reaches, in order from before backwards, the internal jugular vein, the common carotid artery, the vagus, the thoracic duct (on the left side), the middle cervical ganglion of the sympathetic, the inferior thyroid artery, the vertebral vessels, the recurrent laryngeal nerve, and the œsophagus. The most important bony landmark in this triangle is the prominent anterior tubercle of the transverse process of the sixth cervical vertebra. The common carotid artery may be compressed against this tubercle, which is therefore termed the "*carotid tubercle.*" As it is the most important guide to the vertebral artery, which enters the foramen in its transverse process, it is often referred to as the "*vertebral arterial tubercle.*"

In operations in this region, on the left side, it is important to avoid the **thoracic duct**, which extends upwards into the neck 1 in. vertically above the inner end of the clavicle, and, after arching outwards behind the common carotid, descends behind the lower inch of the internal jugular vein.

The **cervical portion** of the **œsophagus**, which begins at the level of the cricoid cartilage, descends behind, and a little to the left of, the trachea. To expose it, the surgeon, after passing through the above-mentioned muscular triangle, passes between the trachea and the carotid sheath. In opening the œsophagus care must be taken not to injure the **recurrent laryngeal nerve** which ascends in the groove between it and the trachea, and also that the loose submucous cellular interval must not be mistaken for the lumen of the tube. The recurrent laryngeal nerve must be avoided also in operations connected with the thyroid gland; it is most liable to be injured during the application of a ligature to the **inferior thyroid artery**, which arches inwards in front of the nerve to reach the posterior surface of the gland.

The Posterior Triangle.—Imbedded in the deep cervical fascia at the posterior border of the sterno-mastoid muscle, is a chain of **lymphatic glands** which lies in close relation to the branches of the cervical plexus; these glands are a frequent source of abscess in pediculosis and impetigo of the scalp. The posterior belly of the omo-hyoid, which forms the upper boundary of the **supraclavicular division** of the posterior triangle, passes beneath the posterior border of the sterno-mastoid at a point about 1 in. above the clavicle. The **external jugular vein**, usually visible through the skin, runs in a line from the angle of the jaw to the middle of the clavicle; it is the vessel which is generally opened to relieve the right side of the heart in asphyxia. The lumen of the vein is kept patent where it pierces the fascia of the subclavian triangle; hence a wound of the vein in this situation is liable to be followed by the suction of air into the circulation during inspiration. The **third part** of the **subclavian artery** can be compressed against the first rib by pressing downwards and backwards immediately above the clavicle, a little behind the posterior border of the sterno-mastoid muscle. To map out the *course* of the subclavian artery in the neck, draw a line, convex upwards, from the upper border of the sterno-clavicular articulation to the middle of the clavicle, the highest part of the arch to reach from ½ to 1 in. above the bone. To *ligature the vessel* in the third part of its course, an angular incision is made along the middle of the upper border of the clavicle and the lower part of the posterior border of the sterno-mastoid muscle. The most important guides to the vessel are the posterior belly of the omo-hyoid, the outer border of the scalenus anticus, and the scalene tubercle of the first rib. The close relation of the vessel to the lowest trunk of the brachial plexus and to the cervical pleura must be kept in mind. In the rare instances in which a cervical rib is present the subclavian artery lies either in front of it, or arches above it, according to the degree of development of the rib. The **subclavian vein** lies below, and anterior to the artery, altogether under cover of the clavicle.

Entering the posterior triangle from behind the outer border of the scalenus anticus are the trunks of the **brachial plexus**. They lie upon the scalenus medius, and can be felt through the skin immediately above and behind the third part of the subclavian artery. The carotid tubercle lies between the anterior primary divisions of the sixth and seventh cervical nerves. The fifth cervical nerve is that which suffers most when the plexus is injured by forcible extension upwards of the arm, such as occurs, for instance, in the "Obstetrical Paralyses" of Duchenne.

In the middle line of the neck posteriorly is the **nuchal furrow**, at the bottom of which are the cervical spines and the ligamentum nuchæ. At the upper part of the furrow, about 2 in. below the external occipital protuberance, is the large **spine of the axis**, which can be distinctly felt; a line drawn from it outwards and slightly upwards to the transverse process of the atlas corresponds to the position of the inferior oblique muscle and, therefore, to the lower margin of the **sub-occipital triangle**. The course of the deep part of the **great occipital nerve** may be mapped out by drawing a line from the centre of the above-mentioned line to a point one inch external to the external occipital protuberance. At the floor of the sub-occipital triangle is the posterior arch of the atlas upon which the **vertebral artery** lies.

THE THORAX.

For the convenience of topographical description, clinicians, by the use of vertical and transverse lines, have arbitrarily divided the surface of the chest into certain definite regions or areas. The vertical lines are: the *mid-sternal*, the *lateral sternal*, the *para-sternal*, the *mammary* or *mid-clavicular*, the *anterior*, *mid*, and *posterior axillary*, and the *scapular*. The position of the mid and lateral sternal lines is sufficiently indicated by their names.

The **mammary**, better termed the **mid-clavicular**, is drawn vertically down from the centre of the clavicles, or, what comes to practically the same thing, from a point midway between the centre of the supra-clavicular notch and the tip of the acromion process. In the male this line usually lies $\frac{1}{2}$ to $\frac{3}{4}$ in. internal to the centre of the nipple, which is usually placed over the fourth interspace, or fifth rib, four inches from the middle line. In the child the nipple may be as high as the lower border of the third rib. In the female the position of the nipple is so variable that it is of no topographical value. In a well-proportioned subject, the mid-clavicular line, if prolonged downwards, will be found to be continuous with the vertical Poupart line, which crosses the costal margin at the tip of the ninth costal cartilage.

The **para-sternal line**, drawn midway between the lateral sternal and mid-clavicular, crosses the costal margin opposite the tip of the eighth costal cartilage.

The **anterior**, the **mid**, and the **posterior axillary lines** are respectively drawn downwards from the anterior fold, the apex, and the posterior fold of the axilla.

The **scapular line** is drawn perpendicularly through the inferior angle of the scapula.

Of the *two transverse lines*, the **upper**, which separates the **infra-clavicular** and **supra-sternal** regions from the **mammary** and **infra-sternal** regions, is drawn at the level of the third chondro-sternal articulation; the **lower**, which separates the **mammary** and **infra-mammary** regions, is drawn at the level of the sixth chondro-sternal articulation.

The lateral area of the chest is divided into an upper, or **axillary**, and a lower, or **infra-axillary** region, by a horizontal line drawn at the level of the sixth rib.

In muscular subjects there is a well-marked mesial furrow, the **sternal furrow**, between the sternal origins of the **pectoralis major muscles**. The inner part of the lower border of these muscles forms a curved prominence which, overlying the fifth rib, corresponds to the junction of the mammary and infra-mammary regions. Below this prominence is the infra-mammary region, which forms a somewhat flat surface corresponding to the upper part of the rectus muscle. In the axillary and infra-axillary regions are the prominences caused by the digitations of origin of the **serratus magnus**, the first to appear below the pectoralis major being that which springs from the fifth rib.

The **upper border** of the **sternum** lies in the same horizontal plane as the lower border of the body of the second dorsal vertebra, the distance between the two being about 2 in. The junction of the manubrium and the body of the sternum forms a slight prominence or angle, known as the *angulus Ludovici*, which, although not usually visible, may always be felt. The angulus lies in the same plane as the body of the fifth dorsal vertebra.

The **xiphi-sternal junction** corresponds to the disc between the ninth and tenth

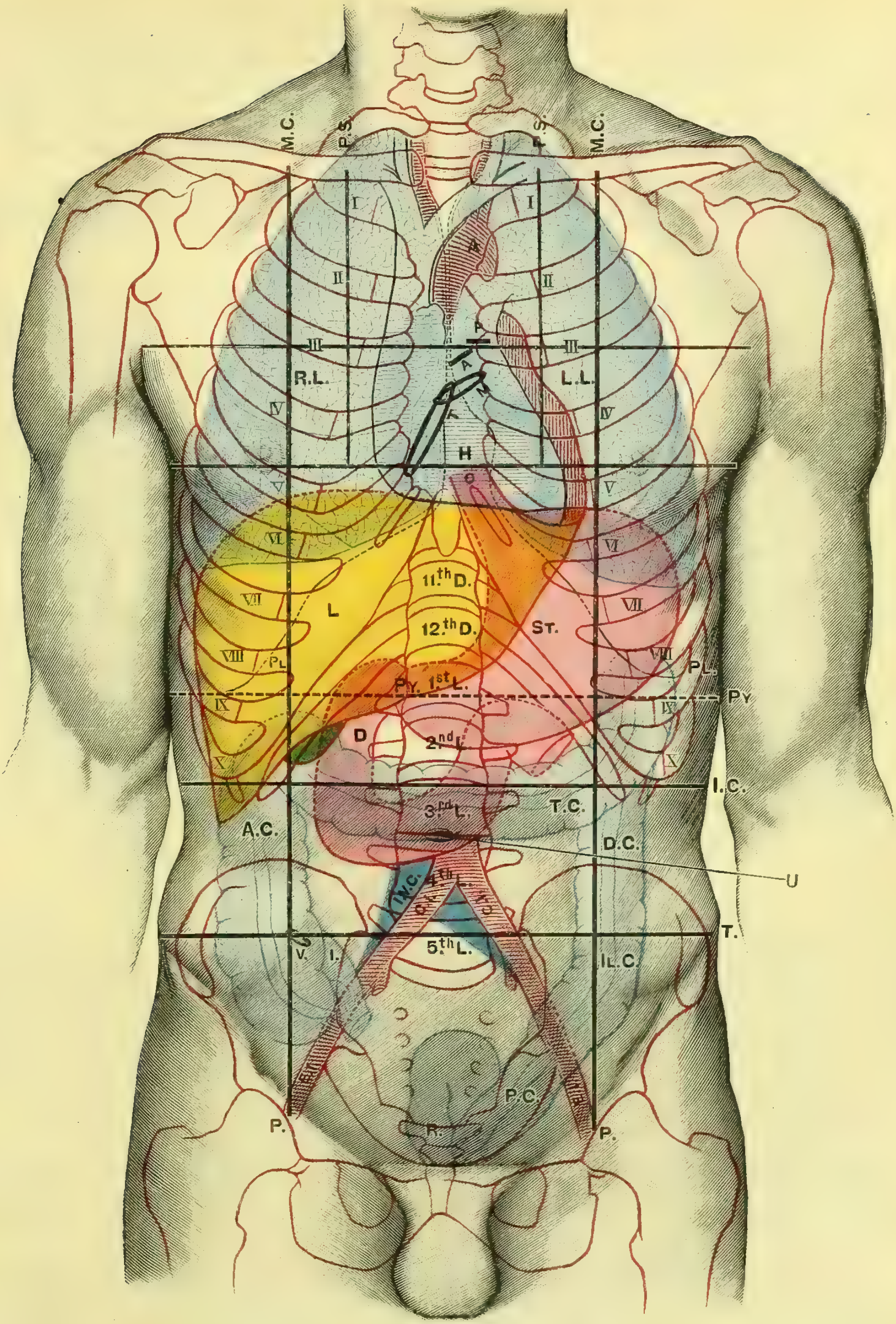

FIG. 801.—ANTERIOR ASPECT OF TRUNK, SHOWING SURFACE TOPOGRAPHY OF VISCERA.

M.C. Mid-clavicular line.
P.S. Para-sternal line.
P. Poupart vertical line.
I.C. Infracostal line.
T. Intertubercular line.
Py. Transpyloric line of Addison.
A. Aorta.
H. Heart.
P. Pulmonary orifice.
A. Aortic orifice.
M. Mitral orifice.

T. Tricuspid orifice.
R.L. Right lung.
L.L. Left lung.
Pl. Pleura.
L. Liver.
O. Œsophagus.
St. Stomach.
Py. Pylorus.
D. Duodenum.
I. Ileum.
V. Ileo-cæcal valve.

A.C. Ascending colon.
T.C. Transverse colon.
D.C. Descending colon.
Il.C. Iliac colon.
P.C. Pelvic colon.
R. Rectum.
C.I. Common iliac artery.
E.I. External iliac artery.
I.V.C. Inferior vena cava.
U. Umbilicus.

dorsal vertebræ. Immediately below the xiphi-sternal articulation is the **infra-sternal notch**, formed by the junction of the seventh costal cartilages with the sternum. Below the notch is the **epigastric fossa** or **triangle**, bounded laterally by the seventh costal cartilages. The apex of the triangle forms an angle which varies considerably according to the shape of the chest, the average being about 70°. Not infrequently the eighth costal cartilage articulates with the sternum.

Fracture of the sternum is rare, and generally occurs at or close to the junction of the manubrium and the body; it may occur either from direct violence, or indirectly along with fracture of the spine. Unlike that of the ribs, the periosteum covering the sternum is firmly adherent to the bone.

The **ribs**, which in well-nourished subjects cause no surface prominences, are readily visible in thin persons; in the obese they are very difficult to feel. In counting the ribs from the front, the *second* may always be identified by its relation to the angulus Ludovici. The *first rib* is to a large extent under cover of the clavicle. The lower border of the pectoralis major and the first visible digitation of the serratus magnus afford reliable guides to the *fifth rib*. The infra-sternal notch is the guide to the inner end of the *seventh costal cartilage*. The second and third costal cartilages are practically horizontal; below this the cartilages ascend with increasing obliquity, that of the sixth being the first to present a distinct angle. The inner end of the second intercostal space is the widest, while those of the fifth and sixth are very narrow.

The **costo-chondral junctions** may be indicated on the surface by a line drawn from the upper end of the para-sternal line to a point a finger's breadth behind the angle of the tenth costal cartilage.

The **internal mammary artery** crosses behind the inner ends of the upper five intercostal spaces about ½ in. from the edge of the sternum; as it descends it approaches a little nearer to the sternum. The vessel is accompanied by two veins which unite to form a single vein opposite the second interspace.

This artery is occasionally injured in punctured wounds of the chest. At the second or third intercostal space it is easily ligatured through a transverse incision, but at a lower level it is generally necessary to resect a portion of one of the costal cartilages.

THE LUNGS.

The **apex** of the lung extends upwards into the root of the neck for a distance of 1 to 2 in. above the anterior extremity of the first rib, and is mapped out by a curved line drawn from the upper border of the sterno-clavicular articulation across the sterno-mastoid to the junction of the inner and middle thirds of the clavicle, the highest part of the curve reaching from ½ to 1½ in. above the clavicle. The apex of the right lung reaches ½ in. higher than that of the left lung. Intimately related to the apex of the cervical pleura are the subclavian artery and the **inferior cervical ganglion** of the sympathetic.

Both the **cervical pleura** and the **subclavian artery** may be injured by one of the fragments in a fracture of the clavicle; the scaleni muscles, however, affording considerable protection to the former. In ligaturing the third part of the subclavian artery, care must be taken not to injure the cervical pleura.

To delineate the **anterior border** of the **right lung**, draw a line from the upper border of the sterno-clavicular articulation to the centre of the manubrium sterni, and from thence vertically downwards, in or slightly to the left of the middle line, to the level of the sixth or seventh costal cartilage, or it may be even to the infra-sternal notch.

The **anterior border** of the **left lung** is mapped out by a corresponding line as far as the fourth costal cartilage; thence it is directed outwards along the lower border of the fourth costal cartilage to the para-sternal line; it then passes downwards and slightly outwards across the fourth interspace, and curves inwards behind the fifth costal cartilage and fifth interspace to reach the upper border of the sixth costal cartilage in the para-sternal line. The lower part, therefore, of the anterior surface of the right ventricle is uncovered by lung and gives a completely

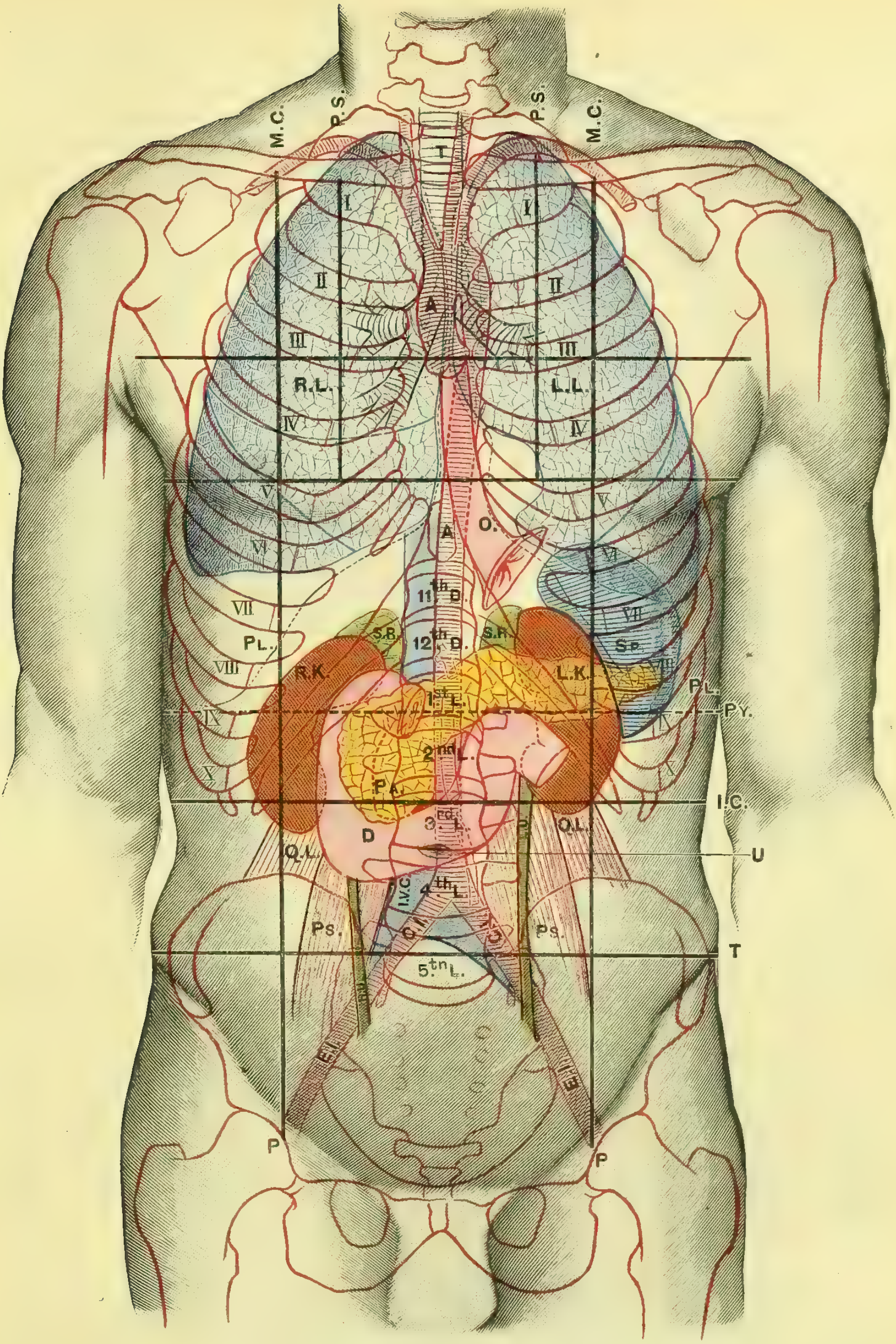

Fig. 802.—Anterior Aspect of Trunk, showing Surface Topography of Viscera.

M.C. Mid-clavicular line.
P.S. Para-sternal line.
P. Poupart vertical line.
I.C. Infracostal line.
T. Intertubercular line.
Py. Transpyloric line.
T. Trachea.
A. Aorta.
R.L. Right lung.

L.L. Left lung.
Pl. Pleura.
O. Œsophagus.
R.K. Right kidney.
L.K. Left kidney.
Sp. Spleen.
S.R. Suprarenal capsule.
Pa. Pancreas.
D. Duodenum.

Q.L. Quadratus lumborum.
P.S. Psoas.
R.U. Right ureter.
L.U. Left ureter.
C.I. Common iliac artery.
E.I. External iliac artery.
I.V.C. Inferior vena cava.
U. Umbilicus.

dull note on percussion; this area is spoken of as the area of "*superficial or absolute cardiac dulness.*"

The level of the **lower border** of the lung is practically the same on both sides; it is mapped out by a line extending outwards from the lower extremity of the anterior border and passing through the sixth costal cartilage in the mid-clavicular line, and thence in a slightly curved direction, with the convexity downwards, across the lateral aspect of the chest to the tenth dorsal spine. This line crosses the eighth rib in the mid-axillary line and the tenth rib in the scapular line.

To indicate the position of the **oblique fissures** a line is drawn from the second dorsal spine across the interscapular region to the root of the spine of the scapula, and thence downwards and outwards across the infraspinous fossa, to end at the lower border of the lung opposite the sixth costal cartilage, a finger's breadth external to the para-sternal line. When the arm is raised above the level of the shoulder, and the hand placed on the back of the head, the inferior angle of the scapula is rotated upwards and forwards so that the vertebral border practically corresponds with the line of the oblique fissure.

The **transverse fissure** of the right lung is mapped out by drawing a line from the anterior border of the lung, at the level of the fourth costal cartilage, outwards and slightly upwards to join the middle of the oblique fissure.

Pleura.—The **line of reflexion** of the **right pleura** from the back of the sternum may be said to correspond to the anterior border of the right lung.

On the **left side**, the pleural reflexion corresponds to the anterior border of the left lung as far as the lower edge of the fourth chondro-sternal junction, from which point it diverges slightly and descends behind the left border of the sternum to the sixth costal cartilage.

The **right costo-diaphragmatic reflexion** (see Figs. 802 and 803) is indicated on the surface by a line drawn from the seventh chondro-sternal junction (sometimes the infra-sternal notch) downwards and outwards to a point 2 in. vertically above the angle of the tenth costal cartilage; from this point the line is carried with a slightly downward curve across the lateral aspect of the chest to the twelfth rib at the outer margin of the erector spinæ; thence it passes below the twelfth rib and reaches the vertebral column at the level of the upper border of the twelfth dorsal spine.

The **left costo-diaphragmatic reflexion** is indicated by a line drawn from a point opposite the sixth costal cartilage, a finger's breadth from its junction with the sternum, to a point one and a half inches vertically above the angle of the tenth costal cartilage, and thence to the spine, as on the right side, but at a slightly lower level.

The costo-diaphragmatic reflexion reaches its *lowest limit* in the mid-axillary line two inches vertically above the tip of the eleventh costal cartilage, a level which may be readily indicated, according to Cunningham, by a point in the mid-axillary line intersected by a horizontal line drawn round the trunk at the level of the lowest part of the extremity of the first lumbar spine. The same author localises the level of the diaphragmatic pleural reflexion in the mammary line at the point where this line is intersected by another horizontal line at the level of the spine of the last dorsal vertebra.

The **relations** of the **pleura** to the **twelfth rib** are of importance to the surgeon, especially in connexion with operations on the kidney (Fig. 631, p. 931). When this rib is not abnormally short, the pleural reflexion crosses it opposite the outer border of the erector spinæ muscle, hence an incision may be carried deeply as far as the apex of the angle formed by the twelfth rib and the outer border of the erector spinæ without entering the pleura. When, however, the twelfth rib does not reach the outer border of the erector spinæ, an incision carried upwards into the apex of the angle between this muscle and the eleventh rib is certain to wound the pleura (Melsome). It is important, therefore, to count the ribs from above downwards, in order not to mistake the eleventh for the twelfth, when the latter is rudimentary.

Internal to the outer edge of the erector spinæ the pleural reflexion lies below the level of the twelfth rib, and not infrequently descends as far as the transverse process of the first lumbar vertebra.

On the *right side* the **posterior mediastinal pleura** passes inwards in front of the vertebræ, forming a slight cul-de-sac between them and the œsophagus. On the *left*

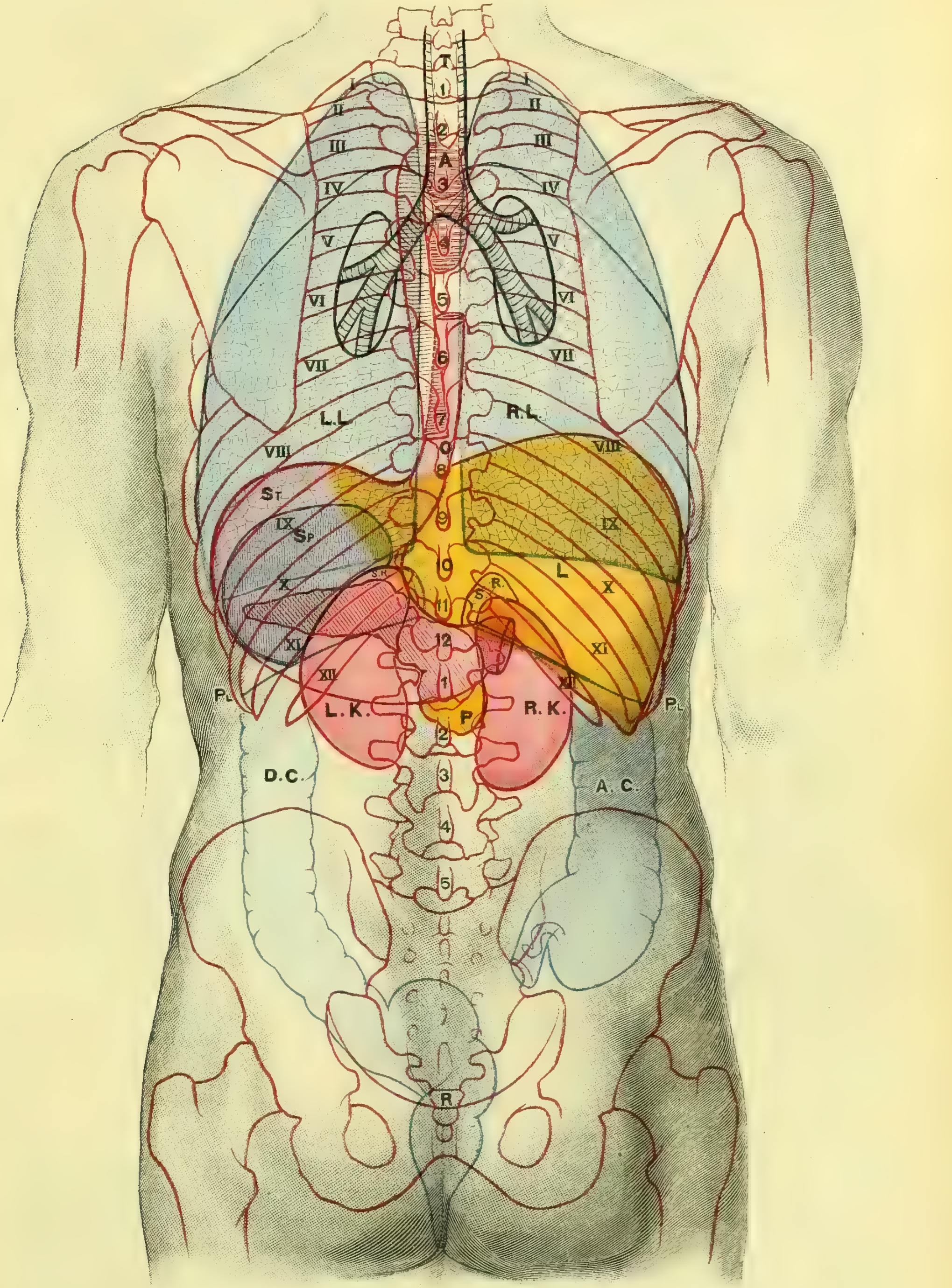

FIG. 803.—POSTERIOR ASPECT OF TRUNK, SHOWING SURFACE TOPOGRAPHY OF VISCERA.

T.	Trachea.	Sp.	Spleen.	P.	Pancreas.
A.	Aorta.	L.	Liver.	Pl.	Pleura.
L.L.	Left lung.	S.R.	Suprarenal body.	D.C.	Descending colon.
R.L.	Right lung.	L.K.	Left kidney.	A.C.	Ascending colon.
St.	Stomach.	R.K.	Right kidney.	R.	Rectum.

side the posterior mediastinal pleura passes from the lateral aspect of the bodies of the vertebræ on to the left side of the aorta. Hence, to evacuate pus from the posterior

mediastinum, there is less risk of opening the pleura if the space be entered from the left side of the vertebral column.

The seat of election for *tapping the pleura* (*paracentesis pleuræ*) is the sixth or seventh costal interspace a little in front of the posterior axillary fold. To allow of the introduction of a tube to drain away the pus from the pleural cavity in empyema, a portion of one of the ribs (sixth to ninth) is resected. The intercostal vessels and nerves, which lie in the groove at the lower border of the rib, are avoided by removing the portion of bone subperiosteally. If the chest is opened in the scapular line care must be taken not to resect either the seventh or the eighth ribs, which are exposed when the arm is elevated, but overlapped by the angle of the scapula when the arm is lowered.

Anteriorly, the **bifurcation** of the **trachea** lies at or a little below the *angulus Ludovici*, while posteriorly it lies a little below the level of the root of the spine of the scapula, opposite the interval between the third and fourth dorsal spines. The bifurcation takes place one vertebra higher in the infant than in the adult (Symington).

The right bronchus is wider and more nearly in a line with the trachea than the left bronchus, hence the greater tendency of foreign bodies to enter the former.

The **roots** of the **lungs** are situated opposite the fourth, fifth, and sixth dorsal spines, midway between them and the vertebral borders of the scapulæ.

The lower end of the trachea, the bronchi, the vagi, and the left recurrent laryngeal nerve, are all more or less surrounded by lymphatic glands, which, when enlarged, may exert injurious pressure upon them.

THE HEART AND GREAT VESSELS.

Viewed from the front, the **outline** of the **precordial area**, like that of the pericardial sac, is roughly triangular, the base of the triangle being below and the apex above. The boundaries are delineated upon the surface as follows:—

The *right side* of the triangle, formed by the right auricle, is indicated by drawing a line slightly convex outwards from the upper end of the third to the sixth (frequently the seventh) right chondro-sternal junctions; the curve attains its maximum opposite the fourth intercostal space, where it reaches $1\frac{1}{2}$ in. from the middle line.

The *base* of the triangle, formed by the *margo acutus* of the right ventricle and to a very slight extent by the apical portion of the left ventricle, is almost horizontal, and corresponds to a line drawn from the sixth or seventh right chondro-sternal junction to the apex of the left ventricle, which lies behind the fifth left intercostal space, $3\frac{1}{2}$ in. from the middle line and $\frac{1}{2}$ in. internal to the mid-clavicular line. The base line crosses the xiphoid cartilage a little below its junction with the body of the sternum.

The *left side* of the triangle, formed by the *margo obtusus* of the left ventricle, is indicated by a slightly curved line extending from the apex of the heart upwards and inwards to the lower edge of the second left chondro-sternal articulation, the convexity of the curve being directed outwards and slightly upwards.

The truncated *apex* of the triangle, which lies behind the sternum at the level of the second intercostal space, corresponds to the highest part of the heart, namely, where the auricular appendices embrace the aorta and pulmonary artery.

The anterior part of the right **auriculo-ventricular groove** is mapped out by a line drawn from the middle line, opposite the lower border of the third right costal cartilage, downwards and outwards to the sixth right chondro-sternal junction; the line should be slightly convex upwards and to the right. The **right auricular appendix** lies at, or a little to the left of, the middle line, at the level of the second intercostal space and the upper border of the third costal cartilage. The **left auricular appendix** lies behind the second left intercostal space, close to the edge of the sternum.

The *inferior surface* of the heart (facies diaphragmatica) rests upon the diaphragmatic or basal part of the pericardium. The true *posterior surface* of the heart is formed mainly by the **left auricle**, which is moulded posteriorly upon the œsophagus, the left bronchus and the bronchial glands, the pericardium intervening.

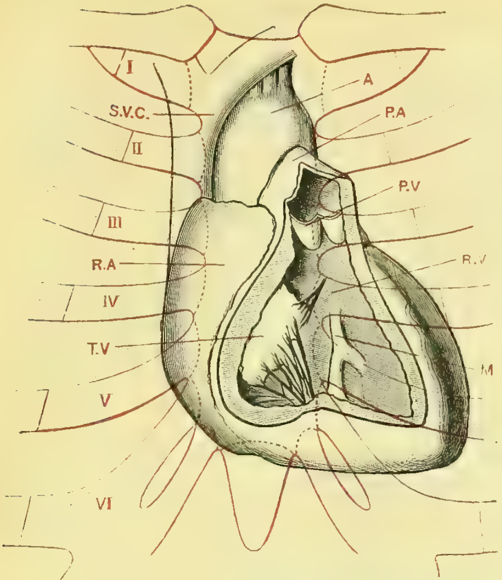

Fig. 804.

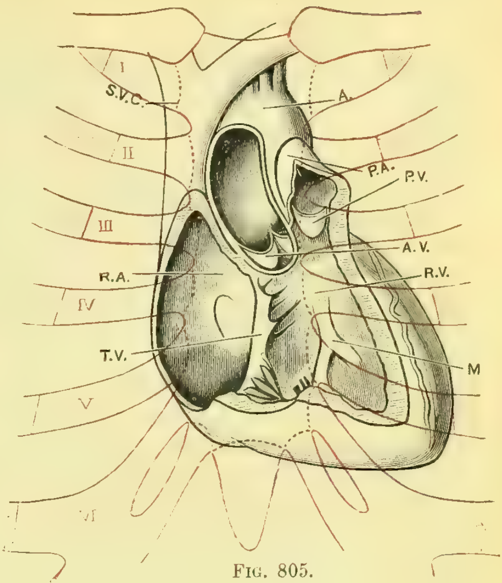

Fig. 805.

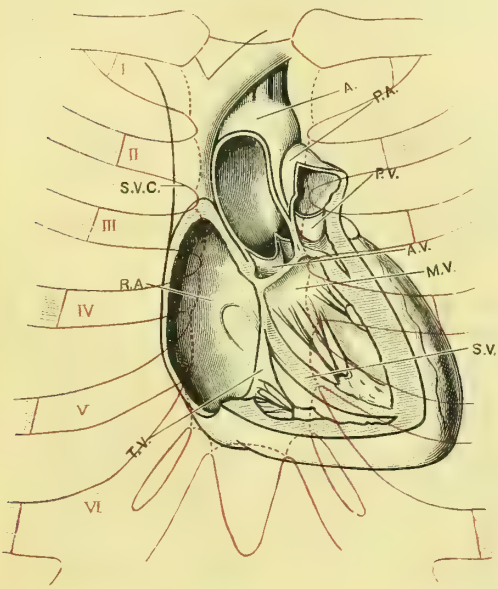

Fig. 806.

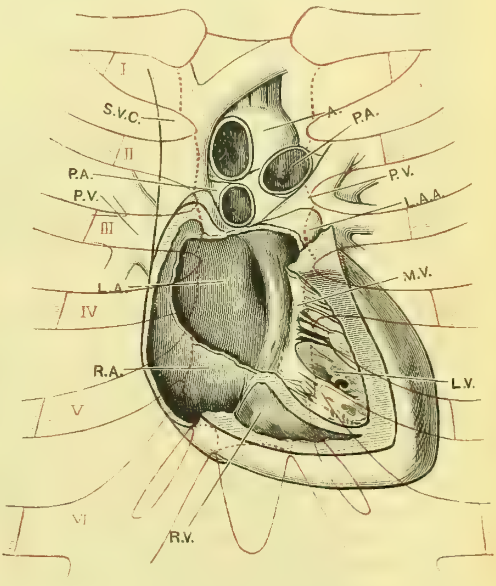

Fig. 807.

From photographs of a formalin-hardened subject, with the heart dissected *in situ*, to show the relations of its cavities and valves to the anterior wall of the thorax.

In Fig. 804 the anterior wall of the right ventricle has been removed and the pulmonary artery opened.

In Fig. 805 the anterior walls of the ascending aorta and of the right auricle have been removed; also the anterior cusp of the tricuspid valve.

In Fig. 806 the greater part of interventricular septum has been removed, exposing anterior cusp of mitral valve.

In Fig. 807 the ascending aorta, anterior cusp of mitral valve, trunk of pulmonary artery, and interauricular septum have been removed; the cavities of left auricle and left ventricle are exposed, also the left auricular appendix and posterior cusp of mitral valve.

R.A.	Right auricle.	P.A.	Pulmonary artery.	M.V.	Mitral valve.
R.V.	Right ventricle.	P.V.	Pulmonary valve.	S.V.C.	Superior vena cava.
L.A.	Left auricle.	A.	Aortic arch.	P.V.	Pulmonary vein (in Fig. 807).
L.A.A.	Left auricular appendix.	A.V.	Aortic valve.	M.	Moderator band.
S.V.	Interventricular septum.	T.V.	Tricuspid valve.		

The left auricle extends behind the right auricle for a considerable distance to the right of the mesial plane.

In determining the position of the *cardiac orifices* and *their valves* it is to be remembered that they are all situated to the left of the right auriculo-ventricular groove, and that they lie in the following order from above downwards—viz. pulmonary, aortic, mitral, and tricuspid. When delineated on the surface they will be seen to lie within an ellipse whose long axis extends from the upper border of the third left to the sixth right chondro-sternal junction.

The **pulmonary orifice**, directed upwards and slightly backwards and to the left, lies opposite the upper part of the third left chondro-sternal junction; the **aortic orifice**, directed upwards, backwards, and to the right, lies further from the surface, behind the left half of the sternum, opposite the lower border of the third costal cartilage; the **mitral orifice** lies at a lower level behind the left half of the sternum, opposite the fourth rib; the orifice of the opening is directed downwards, forwards, and to the left. The **tricuspid orifice**, situated nearer the anterior wall of the chest than the mitral, lies opposite the middle of the sternum at the level of the fourth and fifth cartilages and intervening space; the orifice, which is placed very obliquely, may be represented upon the surface by an ellipse placed parallel to and immediately to the left of the middle two-fourths of the line indicating the anterior part of the right auriculo-ventricular groove.

Although the first and second **sounds of the heart** are heard all over the cardiac area, the sounds produced by the individual valves are heard most distinctly, not directly over their anatomical situation, but over the area where the cavity in which the valve lies approaches nearest to the surface. Hence the mitral sound is best heard over the apex (mitral area), the tricuspid over the lower part of the body of the sternum (tricuspid area), the aortic over the second right costal cartilage (aortic area), and the pulmonary over the second left intercostal space (pulmonary area).

In **tapping the pericardium** (paracentesis pericardii) the pleura will be avoided by making the puncture through the fifth or sixth left intercostal space as close as possible to the edge of the sternum. When, however, the pericardial sac is distended with fluid, the pleura is pushed outwards, and will therefore escape injury if the puncture be made at a safe distance external to the internal mammary vessels, viz. 1 in. external to the left border of the sternum.

To establish free drainage in suppurative pericarditis, the sixth left costal cartilage must be resected and the internal mammary vessels ligatured; the triangularis sterni and the pleural reflexion are then pushed aside and the pericardium exposed and incised.

The **ascending aorta** lies behind the sternum, opposite the second and third ribs, and, unless dilated, does not project beyond its right border. The upper border of the **aortic arch** lies at or a little above the centre of the manubrium sterni; in the child the vessel may reach as high as the upper border of the manubrium.

The **innominate** and **left common carotid arteries** diverge from either side of the mesial plane between the upper part of the manubrium sterni and the front of the trachea. A pin pushed directly backwards immediately above the middle of the supra-sternal notch will strike the inner border of the innominate artery a little below its bifurcation.

The **pulmonary artery** lies behind the left border of the sternum opposite the second interspace and the second costal cartilage.

The **left innominate vein** lies behind the upper part of the manubrium sterni, the **right** behind the inner end of the right clavicle. The **superior vena cava** lies behind and a little to the right of the margin of the sternum, opposite the first and second interspaces and the intervening second rib; its opening into the right auricle, behind the third chondro-sternal articulation, corresponds to the centre of the root of the right lung.

Œsophagus.—The average length of the œsophagus in the adult is 10 in. (25 cm.); the distance from the incisor teeth to its commencement is 6 in.; to the point or level where it is crossed by the left bronchus, 9 in.; to the œsophageal opening of the diaphragm, 14 to 15 in.; to the cardiac orifice of the stomach, 16 in. These measurements, which are of great importance in diagnosing the seat of œsophageal obstructions, should be marked off from below upwards upon all œsophageal bougies and probangs. Posteriorly, the œsophagus extends from the level of the sixth cervical spine to that of the ninth dorsal, a little to the left of

which is the situation at which the stethoscope is placed in order to hear the sound produced by the passage of fluid into the stomach.

Clinically it is important to bear in mind the relation of the œsophagus to the trachea and bronchi (especially to the left bronchus), to the left recurrent laryngeal nerve, to the bronchial and posterior mediastinal glands, to the descending thoracic aorta, and to the right posterior mediastinal pleura. Ulcers of the œsophagus are liable to open into either the trachea, the left bronchus, or the right pleura.

The *veins* of the lower end of the œsophagus open partly into the systemic veins and partly into the portal system; like those at the lower end of the rectum they are liable to become varicose in conditions which give rise to chronic interference with the portal circulation.

The *lymphatics* of the upper part of the œsophagus open into the lower carotid glands, the remainder into the posterior mediastinal glands.

The œsophagus is very distensible in the transverse but not in the antero-posterior direction, hence the most useful forceps for removing foreign bodies from the œsophagus are those which open laterally.

THE BACK.

In the middle line of the back is the **spinal furrow**, which is deepest in the lower dorsal and upper lumbar regions, where the erectores spinæ muscles are most prominent. Over the upper sacral region, where the erectores spinæ muscles are tendinous, is a flattened area forming an equilateral triangle, the angles of which correspond respectively to the posterior superior spines of the two iliac bones and the third sacral spine. The **vertebral spines** can be palpated at the bottom of the spinal furrow; they become more distinct when the spine is flexed, and, as pointed out by Holden, they become mapped out by reddened areas when friction is applied along the furrow. The identification and counting of the spines will be facilitated if it be remembered that the first dorsal is more prominent than the vertebra prominens (seventh cervical), that the third dorsal is on a level with the root of the spine of the scapula, the seventh dorsal with its inferior angle, the fourth lumbar with the highest part of the iliac crest, and the second sacral with the posterior superior iliac spine.

Above the spine of the scapula is the **suprascapular region**, which is padded by a thick mass of muscle consisting of the supra-spinatus and levator anguli scapulæ, covered by the upper part of the trapezius; the two latter muscles may be thrown into relief by shrugging the shoulders.

In the **interscapular region** are the rhomboid muscles, which are thrown into prominence by bracing back the shoulders.

Below the inferior angle of the scapula the last five ribs can readily be felt external to the erector spinæ muscle; when the twelfth rib does not reach beyond this muscle, the eleventh rib will be mistaken for it, unless the ribs be counted from above downwards.

The **lower border of the trapezius** is indicated by a line extending upwards and outwards from the twelfth dorsal spine to the root of the spine of the scapula; the **upper border of the latissimus dorsi** by a line extending from the sixth dorsal spine transversely outwards across the angle of the scapula. Between these two muscles and the lower part of the vertebral border of the scapula is a triangular area, the floor of which is formed by the rhomboideus major muscle and the sixth costal interspace.

The outer border of the **erector spinæ** is indicated on the surface by drawing a line from a point on the iliac crest 3½ in. (four fingers' breadth) from the middle line, upwards and slightly outwards to the angles of the ribs. The outer border of the **quadratus lumborum**, which passes upwards and slightly inwards, lies a little external to that of the erector spinæ at the crest, and a little internal to it at the twelfth rib.

The anatomy of the muscles and fasciæ which complete the abdominal wall between the last rib and the iliac crest is of great importance in connexion with operations in the **region of the loin**. The space between the last rib and the iliac crest varies greatly according to the length of the former, and according to the general shape of the chest and slope of the ribs. As a rule, the **tip of the twelfth rib** lies about two inches vertically above the centre of the iliac crest. From a surgical

point of view the costo-iliac space may be said to be limited internally by the outer edge of the erector spinæ, and, more deeply, by the tips of the transverse processes of the lumbar vertebræ, while externally it is bounded by the posterior free border of the external oblique, and, more deeply, by the line of reflexion of the peritoneum from the colon on to the lateral wall of the abdomen. The space is roofed over by the latissimus dorsi, except below, where a narrow triangular interval is left between its outer border and the posterior border of the external oblique, the base of the triangle being formed by the crest of the ilium, a little behind its centre. This triangle (Fig. 250, p. 339), known as the "**triangle of Petit**," represents a weak area through which a lumbar abscess may come to the surface, and through which a lumbar hernia occasionally develops. On removing the latissimus dorsi and the lower part of the thin serratus posticus inferior, another triangle will be exposed, which constitutes a second weak area in the loin; it is bounded above by the last rib, internally by the outer border of the erector spinæ, and externally by the posterior muscular fibres of the internal oblique; the floor of the triangle is formed by the aponeurosis of origin of the transversalis abdominis muscle. At the outer border of the quadratus lumborum this aponeurosis splits into three layers to form two compartments, the anterior enclosing the quadratus lumborum and the posterior the erector spinæ.

Kidneys.—By retracting inwards the erector spinæ and dividing the posterior fibres of the three abdominal muscles, along with the outer fibres of the quadratus, the kidney may be exposed, with the colon lying vertically in front of its outer border. The upper limit of the kidney is indicated by a line drawn transversely across the loin opposite the eleventh dorsal spine, the lower limit by a line on a level with the third lumbar spine. The upper extremity reaches to the eleventh rib; the lower, which lies immediately external to the tip of the transverse process of the third lumbar vertebra, reaches to within 1½ to 2 in. of the crest of the ilium. About a third of the kidney lies above the lower margin of the twelfth rib. The left kidney usually lies about ½ in. higher than the right. The most external point of the outer border lies 4 in. from the middle line, while the hilus lies 1½ in. external to it in front of the interval between the tips of the transverse processes of the first and second lumbar vertebræ.

The psoas muscle intervenes between the postero-internal surface of the kidney and the transverse processes, and protects the organ from injury by a blow directed from the front. Between the upper end of the kidney and the eleventh and twelfth ribs is the diaphragm and the posterior costo-diaphragmatic reflexion of the pleura. The relations of the pleura to the last rib have already been considered (p. 1188).

Posteriorly the course of the upper part of the **ureter** may be indicated by a line drawn vertically upwards from the posterior superior iliac spine to the level of the second lumbar spine; the deep guides are the tips of the transverse processes of the second, third, and fourth lumbar vertebræ, covered by the psoas muscle.

A needle passed through the inner extremity of the eleventh intercostal space will transfix the **suprarenal body**.

The pus of a **perinephritic abscess** occupies the extraperitoneal fatty layer (perirenal fat), and lies, therefore, within the fascial envelope of the abdomen; the pus in a **psoas abscess**, on the other hand, lies external to the fascia. In opening a psoas abscess from behind, a vertical incision is made in the angle formed by the outer border of the erector spinæ and the crest of the ilium; in the deeper part of the dissection the surgeon should keep close to the front of the transverse process of the fourth lumbar vertebra.

Diaphragm, Liver, Stomach, and Large Intestine.—Posteriorly the **right arch of the diaphragm** and the right lobe of the liver extend upwards to the level of the angle of the scapula (eighth rib), while the **left arch** and the fundus of the stomach lie 1 in. lower (eighth interspace); the central tendon reaches up to the eighth dorsal spine. The **right lobe of the liver** is covered posteriorly by the eighth to the twelfth ribs, and is overlapped by the base of the right lung as far as a line drawn horizontally outwards from the tenth dorsal spine; hence, posteriorly, the upper limit of the liver cannot be defined by percussion, and its lower limit merges into the dulness of the loin muscles and kidney.

The **cardiac orifice of the stomach** lies 1 in. to the left of the ninth dorsal spine. The cardiac portion, overlapped by the ninth to the twelfth ribs, extends

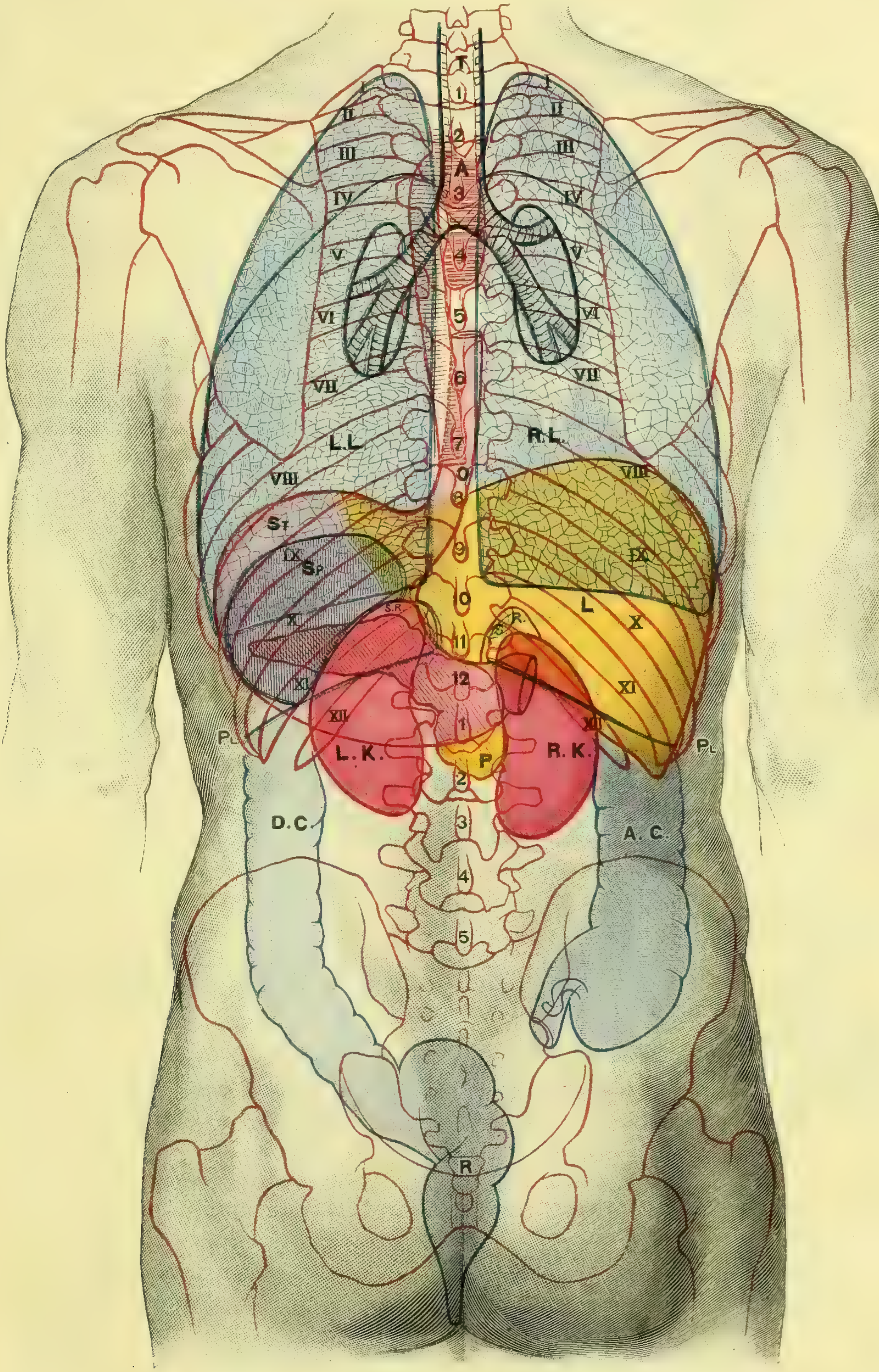

FIG. 808.—POSTERIOR ASPECT OF TRUNK, SHOWING SURFACE TOPOGRAPHY OF VISCERA.

T.	Trachea.	Sp.	Spleen.	P.	Pancreas.
A.	Aorta.	L.	Liver.	Pl.	Pleura.
L.L.	Left lung.	S.R.	Suprarenal body.	D.C.	Descending colon.
R.L.	Right lung.	L.K.	Left kidney.	A.C.	Ascending colon.
St.	Stomach.	R.K.	Right kidney.	R.	Rectum.

upwards to the level of the eighth dorsal spine, 1 in. below the angle of the scapula. The **pyloric portion** crosses the mesial plane opposite the twelfth dorsal and first

lumbar spines, the **pylorus** itself being situated 1 in. to the right of the twelfth dorsal spine. The **lesser curvature** lies to the left of and below the tenth and eleventh dorsal spines.

Viewed from behind, the **large intestine** on both sides overlaps the outer border of the kidneys and lies parallel to the outer border of the erectores spinæ muscles. The peritoneum is reflected from the colon on to the posterior abdominal wall along a line drawn vertically upwards from the centre of the iliac crest. The **splenic flexure**, which reaches up to the level of the twelfth dorsal spine and the tenth rib, lies about 5 in. above the iliac crest. The **hepatic flexure** lies on a level with the first lumbar spine.

Spleen.—The convex, postero-external, or diaphragmatic surface of the spleen is overlapped by the ninth, tenth, and eleventh ribs, the long axis of the organ nearly corresponding to that of the tenth rib (Fig. 785, p. 1150). The spleen is placed further back than is often supposed, its postero-internal or vertebral angle (apex of spleen, according to Cunningham) being situated on a level with, and $1\frac{1}{2}$ in. external to, the tenth dorsal spine. Its antero-external angle (anterior basal angle of Cunningham), which lies on a level with the twelfth dorsal spine, reaches forwards as far as the mid-axillary line, where it is overlapped by the tenth rib. The posterior basal angle lies on a level with, and about 4 in. external to, the first lumbar spine, in a line drawn vertically upwards from a point 1 in. behind the centre of the iliac crest. This angle is situated opposite the eleventh intercostal space, behind the upper part of the descending colon and immediately external to the middle of the outer border of the kidney.

Having placed a mark on the skin corresponding to these three angles, the outline of the organ is delimited as follows:—Commencing at the vertebral angle, the *upper border* is arched upwards so as to reach the level of the ninth rib in the scapular line, thence it descends across the posterior axillary line, as the so-called *anterior notched border*, to end in the mid-axillary line at the antero-external angle. The postero-inferior or *renal border* is drawn from the vertebral to the inferior (posterior basal) angle along the eleventh intercostal space. The short *antero-inferior border* unites the anterior and posterior basal angles. The upper third of the spleen is overlapped by the base of the lung (diaphragm and pleura intervening), which crosses it horizontally at the level of the tenth dorsal spine; hence the upper limits of the spleen cannot be defined by percussion. The postero-inferior limit of the splenic dulness merges into that of the kidney and the thick muscular tissues of the loin. The only parts of the splenic outline, therefore, which can be defined by percussion are part of the upper arched border, and the antero-external and short antero-inferior borders. The dull area lies between the posterior and mid-axillary lines, and reaches down to within about two inches of the costal region.

Pancreas.—The head of the **pancreas** lies opposite the last dorsal and first lumbar spines; the tail lies at the same level as the splenic flexure of the colon, a little above the posterior basal angle of the spleen (Fig. 735, p. 1089).

TABLE INDICATING THE LEVEL OF THE MORE IMPORTANT STRUCTURES IN RELATION TO THE SPINES OF THE VERTEBRÆ.

Spines of Vertebræ.	Origins of Spinal Nerves.	Level of other Structures.
1 Cervical .	2 Cervical .	Soft palate.
2 ,, .	3 and 4 ,, .	Isthmus of fauces.
3 ,, .	5 ,, .	Upper part of epiglottis.
4 ,, .	6 ,, .	Vocal cords.
5 ,, .	7 ,, .	Crico-thyroid membrane.
6 ,, .	8 ,, .	Arch of thoracic duct. Commencement of trachea and œsophagus.
	1 and 2 Dorsal .	Lower end of cervical enlargement of cord. Inferior cervical ganglion. Apices of lung.
1 Dorsal . .	3 ,, .	Summit of arch of subclavian artery.

TABLE INDICATING THE LEVEL OF THE MORE IMPORTANT STRUCTURES IN RELATION TO THE SPINES OF THE VERTEBRÆ—*Continued.*

Spines of Vertebræ.	Origins of Spinal Nerves.	Level of other Structures.
2 Dorsal	4 Dorsal	Upper angle of scapula. Just above level of highest part of arch of aorta. Episternal notch.
3 ,,	5 and 6 ,,	Root of spine of scapula. Arch of vena azygos major. Highest part of lower lobes of lungs. Termination of transverse portion of arch of aorta. Bifurcation of trachea. Lower limit of superior mediastinum. Angulus Ludovici.
4 ,,	6 ,,	Commencement of descending thoracic aorta. Bronchi. Upper limit of heart.
5 ,,	8 ,,	Centre of root of lung. Mitral orifice.
6 ,,	9 ,,	Tricuspid orifice.
7 ,,	10 ,,	Lower angle of scapula. Orifice of inferior vena cava. Right arch of diaphragm.
8 ,,	11 ,,	Lowest limit of heart. Left arch of diaphragm. Fundus of stomach. Xiphi-sternal articulation.
9 ,,	12 Dorsal and 1 Lumbar	Upper limit of spleen. Cardiac orifice of stomach.
10 ,,	2 Lumbar	Upper end of lumbar enlargement. Lower border of lung, posteriorly. Vertebral angle of spleen (apex of spleen). Upper end of left kidney. Lesser curvature of stomach.
11 ,,	3 and 4 ,,	Lower limit of pleura at vertebral column. Upper end of right kidney. Suprarenal capsule. Body of pancreas. Lesser curvature of stomach.
12 ,,	1, 2, 3 Sacral	Level at which pleura crosses twelfth rib. Lower end of spleen. Splenic flexure of colon. Upper part of head of pancreas. Pylorus and pyloric portion of stomach.
1 Lumbar	4 and 5 ,,	Conus medullaris. Lower limit of pleura (mid-axillary line). Hili of kidneys. Head of pancreas. Hepatic flexure of colon. Portal vein. Second part of duodenum. Greater curvature of stomach. Common bile duct.
2 ,,	. . . .	Commencement of ureters. Lowest part of head of pancreas.
3 ,,	. . . .	Lower limit of cord in child. Lower ends of kidneys. Third part of duodenum.
4 ,,	. . . .	Highest part of crest of ilium. Bifurcation of aorta. Umbilicus.
5 ,,	. . . .	Common iliac arteries. Ileo-cæcal valve.
1 Sacral	. . . .	Sacral promontory.
2 ,,	. . . .	Lower end of subdural space.
3 ,,	. . . .	Upper end of gluteal cleft. Lower limit of sub-arachnoid and subdural spaces.

Spinal Cord.—The spinal cord ends opposite the lower border of the first lumbar spine; in the infant it reaches to the interval between the second and third lumbar spines. The *cervical enlargement* which corresponds to the lower four cervical and the first two dorsal segments ends opposite the seventh cervical spine. The *lumbar enlargement* lies opposite the last three dorsal spines. The five lumbar segments are opposite the ninth, tenth, and eleventh dorsal spines, while the five sacral segments extend from the lower border of the eleventh dorsal to the lower border of the first lumbar spine.

The **sub-dural space** extends down to the level of the second sacral spine. In performing the operation of *lumbar puncture* (Quincke) a fine trochar and cannula is introduced into the subarachnoid space below the level of the cord, the puncture being made $\frac{1}{4}$ to $\frac{1}{2}$ in. to one side of the interspinous ligament in the interval between the third and fourth or fourth and fifth lumbar spines. The instrument should be directed inwards towards the mesial plane and very slightly upwards. In the adult the distance of the thecal sac from the surface is about 2 in., in the infant $\frac{3}{4}$ in.

Fracture-dislocations of the spine are commonest in the lower cervical and dorso-lumbar regions; that is to say, where the movable cervical and lumbar regions join the more fixed dorsal region. The spinal column above the injury is generally displaced forwards, so that the spinal cord is often severely lacerated or completely torn across by the upper end of the portion of the column below the fracture. It is important to remember that in consequence of the shortness of the cord as compared with the spine, the origins of the spinal nerves are at a higher level than their exits from the spinal canal. The distance between their origins from the cord and their exits through the intervertebral foramina becomes greater the further down we descend, the lowest nerve trunks running almost vertically downwards. The cervical nerves leave the spinal canal *above* the vertebræ after which they are named; the dorsal, lumbar, and sacral nerves, on the other hand, leave the canal *below* the correspondingly named vertebræ.

To understand the effect of **lesions of the cord**, it is necessary to be familiar with the sensory and motor distributions of the various spinal segments (see Figs. 422, p. 569, and 424, p. 573). Transverse lesions of the cord *above the fifth cervical spine* (that is, above the disc between the fourth and fifth cervical vertebræ) are quickly fatal from paralysis of respiration, as the phrenic nerve arises mainly from the fourth segment. In transverse lesions of the cervical enlargement the *cutaneous insensibility* does not extend higher than a transverse line at the level of the second intercostal space. The diagnosis of the particular segment involved is arrived at by testing the motor and sensory functions of each segment. The sensory areas corresponding to the *lower four cervical* and the *first two dorsal segments* occupy the upper extremities, and are placed in numerical order from the radial to the ulnar side of the limb. The sensory area corresponding to the *second*, *third*, and *fourth cervical segments* occupy the occipital region of the scalp, the back of the auricle, and the masseteric region, the whole of the neck, and the shoulders and upper part of the chest down to a horizontal line at the level of the anterior end of the third intercostal space. In total transverse lesion of the cord in the *dorsal region*, the upper limit of the anæsthesia is horizontal, and reaches to the level of the terminations of the anterior primary divisions of the spinal nerves which arise from the spinal segment opposite the vertebral injury. Hence the upper limit of the anæsthesia is at a much lower level than that of the injured vertebra. For example, a fracture-dislocation at the level of the eighth dorsal vertebra involves the origin of the tenth dorsal nerve which ends at the level of the umbilicus. The sensory zone corresponding to the *fifth dorsal segment* is at the level of the nipples, that of the *seventh dorsal segment* is at the level of the ensiform cartilage, that of the *tenth* at the level of the umbilicus, while that of the *twelfth* reaches down anteriorly to the upper border of the symphysis. The sensory areas corresponding to the lumbar and sacral segments are seen in Figs. 422 and 424.

THE UPPER EXTREMITY.

THE SHOULDER.

The bony landmarks of the shoulder must be systematically examined in all injuries about this region. The **inner extremity** of the **clavicle** is prominent; its

articulation with the sternum forms essentially a weak joint which is liable to be dislocated, especially from blows upon the outer part of the shoulder which drive the inner end of the clavicle forwards against the weak anterior sterno-clavicular ligament. The **shaft** of the **clavicle**, subcutaneous throughout, is weakest at the junction of its two curves; it is in this region that the bone is so frequently fractured as the result of force transmitted through it to the trunk. The displacement of the outer fragment varies according to whether the break takes place internal or external to the coraco-clavicular ligament; in the former case the weight of the upper extremity, acting through the coraco-clavicular ligament, pulls the outer fragment downwards; when the fracture is external to the ligament, the outer end of the clavicle rotates forwards, but there is no downward displacement. The **outer end** of the **clavicle** is on a plane posterior to its inner end, so that the shoulder is braced backwards away from the thorax; hence in fractures of the clavicle, both inside and outside the coraco-clavicular ligament, the point of the shoulder rotates forwards and inwards. The **acromio-clavicular articulation** is somewhat difficult to feel; the groove which corresponds to it runs in the sagittal direction, and lies $1\frac{1}{4}$ in. internal to the outer border of the acromion, and immediately external to a slight prominence upon the outer extremity of the clavicle. When this joint is dislocated the clavicle almost invariably overrides the acromion, and the summit of the shoulder presents a somewhat conical or "sugar-loaf" appearance.

The **tip** of the **acromion** looks directly forwards, and lies a finger's breadth external to and a little in front of the outer extremity of the clavicle. The **outer border** of the **acromion** can readily be followed to its junction with the spine of the scapula, and the latter to its root, which is situated on a level with the third dorsal spine. The **inner border** of the **acromion** and the posterior border of the outer end of the clavicle meet at an angle into which the point of the finger can be pressed. The **upper angle** of the **scapula**, covered by the trapezius and the supraspinatus muscles, is too deeply placed to be palpated distinctly. The **inferior angle**, and the **internal border**, from the root of the spine downwards, form visible prominences which are readily felt; the former overlies the seventh intercostal space on a level with the seventh dorsal spine, while the latter lies a little internal to the angles of the ribs.

To elicit crepitus in a transverse fracture of the scapula below the spine, the surgeon stands behind the patient and grasps the upper fragment by placing the forefinger upon the coracoid and the thumb upon the spine, while with the other hand he grasps the inferior angle; the two fragments are then moved the one upon the other.

The **tip** of the **coracoid process** may be felt by pressing the finger firmly upon the anterior border of the deltoid at a point 1 in. below the junction of the middle and outer thirds of the clavicle. Internal to the coracoid is a triangular depression which corresponds to the upper end of the interval between the clavicular fibres of the pectoralis major and deltoid muscles. Behind this triangular depression are the termination of the cephalic vein, a lymphatic gland, the first part of the axillary vessels, and the cords of the brachial plexus. By firm pressure in this situation the pulsation of the **axillary artery** can be felt, and by further pressure the circulation in the vessel can be arrested by compressing the artery against the second rib. The *first part* of the axillary artery may be cut down upon either by a transverse incision through the clavicular origin of the pectoralis major, or by a longitudinal incision in the interval between this muscular slip and the deltoid. The **companion vein** lies in front of, as well as to the thoracic side of the artery, thus adding to the difficulty of exposing the vessel. In fractures of the middle third of the clavicle the subclavian vessels are protected by the soft pad formed by the subclavius muscle.

The **upper end** of the **humerus** covered by the deltoid gives rotundity to the shoulder. The **greater tuberosity** projects beyond the acromion, and constitutes the most external bony landmark of the shoulder. When the head of the bone is dislocated, the outer border of the acromion then becomes the most external bony landmark, and the shoulder presents a square contour. The **lesser tuberosity**, small but conical, can be felt through the deltoid. Pointing directly forwards, it lies

1 in. external to and a little below the level of the tip of the coracoid process. In examining the upper end of the humerus for fracture, the tuberosities should be grasped between the finger and thumb of one hand, while the flexed elbow is rotated with the other hand. The **head** of the **humerus** has the same direction as the internal condyle; its lower part can be palpated through the axilla, the arm being meanwhile abducted, to bring the head in contact with the under surface of the capsule. It is through this, the weakest part of the capsule, that the head is driven in the common varieties of dislocation of the shoulder, viz. those due to forcible abduction. The **upper epiphysis** of the humerus includes the head and the greater part of the tuberosities. The capsule is mainly attached to the epiphysis; hence, in children, we find that separation of the upper epiphysis takes the place of dislocation. Disease in the upper end of the diaphysis does not necessarily involve the cavity of the joint. The **bicipital groove** of the humerus, which lies immediately external to the lesser tuberosity, may be mapped out upon the surface by drawing a line, two inches in length, downwards along the axis of the humerus from the tip of the acromion. When there is *effusion into the joint,* the arm becomes slightly abducted, and there is fulness in front, along the line of the long tendon of the biceps. With the elbow at the side the inferior part of the capsule of the shoulder-joint is loose and folded upon itself to form a dependent pocket; if, after an injury, the arm be retained too long in this position, the patient may be unable to abduct the arm in consequence of the formation of adhesions in and around the pouch. To evacuate pus from the shoulder joint, the integuments, deltoid, and capsule should be cut into by an incision passing vertically downwards from the tip of the acromion.

THE AXILLA.

The **anterior fold** of the **axilla**, formed by the lower border of the pectoralis major, extends from the fifth rib to the middle of the anterior border of the deltoid. With the arm abducted, the interval between the sternal and clavicular fibres of the pectoralis major is indicated by a slight groove extending downwards and outwards from the inner end of the clavicle. The sternal fibres, along with the pectoralis minor, are removed in a complete operation for malignant disease of the breast, the pectoral branches of the thoracic axis artery being secured as they cross the interval between the sternal and clavicular portions of the greater pectoral. The **posterior fold** of the **axilla**, formed by the latissimus dorsi and the teres major muscles, is on a lower level than the anterior fold, and leaves the chest a little in front of the inferior angle of the scapula. Between the two folds, and running in the long axis of the limb, from the axilla to the middle of the upper arm, is the prominence of the **coraco-brachialis muscle.** The pulsations of the **third part of the axillary artery** may be felt in the furrow immediately behind this prominence at the junction of the anterior and middle thirds of the outer wall of the axilla.

Female Mamma.—The breast tissue proper is arranged to form a central portion, the *corpus mammæ,* and a peripheral portion, made up of branching processes which radiate into the paramammary fat and become continuous ultimately with the connective-tissue septa of the subcutaneous fatty tissue. The mamma, therefore, has no distinct capsule. In the young adult nullipara, the corpus mammæ is compact and well defined, and contains but little intramammary fat, while the peripheral processes are relatively small. In multipara, the corpus mammæ contains more fat, and the peripheral processes extend more widely into the paramammary fat.

The arrangement and extent of the parenchyma can be well seen by treating the breast with a 5 *per cent solution of nitric acid.* If slices of the fresh organ be placed in this solution for a few minutes and then washed under running water, the albumen of the epithelial cells of the parenchyma is coagulated, while the connective tissue is rendered translucent and somewhat gelatinous. The *ultimate lobules* of the *parenchyma* now appear as little (1 to 2 mm.), dull, opaque, white, sago-like bodies, arranged in grape-like clusters around the finer branches of the ducts.

The parenchyma is prolonged into the peripheral processes, into the suspensory ligaments of Cooper, and into the loose retromammary cellular tissue and pectoral

fascia. The breast tissue, therefore, has a much wider distribution than was formerly supposed. Vertically, it extends from the second rib to the sixth costal cartilage at the angle where it begins to ascend towards the sternum; horizontally, from a little within the lateral border of the sternum, opposite the fourth rib, to the fifth rib in the midaxillary line. The *inner hemisphere* of the mamma rests almost entirely on the pectoralis major; at its lowest part it slightly overlies the upper part of the aponeurosis covering the rectus abdominis muscle. The *upper quadrant* of the *outer hemisphere* rests upon the greater pectoral, on the edge of the lesser pectoral, and to a slight extent on the serratus magnus, upon which it extends upwards into the axilla ("axillary tail" of Spence) as high as the third rib, where it comes into relation with the thoracic group of axillary lymphatic glands. The *remainder of the outer hemisphere* rests almost entirely upon the serratus magnus, except the lowest part which overlaps the digitations of the external oblique arising from the fifth and sixth ribs. It follows, therefore, that *fully one-third of the whole mamma lies inferior and external to the axillary border of the pectoralis major muscle.* The surgeon must cut beyond the above limits if he wishes to remove the whole of the mammary tissue.

The axillary fascia resists the spontaneous rupture of an axillary abscess, which, therefore, tends to spread upwards beneath the pectorals, and towards the root of the neck. To open the abscess the incision should be made upon the inner wall, behind, and parallel to, the long thoracic artery, which runs under cover of the anterior fold.

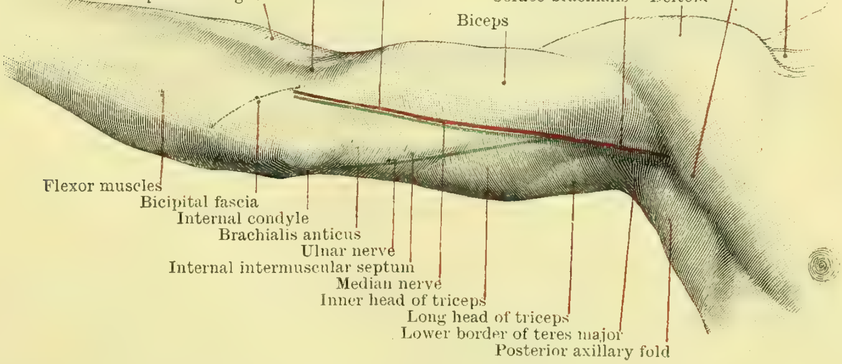

FIG. 809.—AXILLA, INNER ASPECT OF UPPER ARM AND ELBOW.

The **axillary lymphatic glands** vary greatly in size and number; many are no larger than a pin's head. In the female some of them undergo an adipose functional involution, whereby they come to resemble fat lobules. The *central group* (Leaf), embedded in the fat immediately beneath the axillary fascia, become inflamed in poisoned wounds of the upper extremity; the *pectoral group*, related to the inner wall of the axilla and the long thoracic artery, are usually the first to become diseased in affections of the breast. In malignant disease of this organ the *posterior* (subscapular) and the *apical* (subclavicular) *groups* are generally affected, as are also, not infrequently, glands situated between the pectorales major and minor, and in the retro-pectoral fascia in the neighbourhood of the superior thoracic artery (Rotter). In health one or two glands can usually be felt by thrusting the fingers upwards and inwards beneath the anterior fold, the arm being only slightly abducted, so as not to stretch the axillary fascia. In clearing out the axilla for malignant disease, the surgeon removes all the lymphatic glands, and, as far as possible, all fat and fascia, including the sheath of the axillary vein. It must be remembered that the lower part of the axillary vein lies immediately underneath the deep fascia of the outer wall of the axilla; in cleaning the inner wall the long thoracic nerve must not be injured; and in removing the posterior group of lymphatic glands the long subscapular nerve, which accompanies the subscapular vessels, must be avoided, as it is doubly important to retain the action of the latissimus dorsi after removing the pectorals.

THE UPPER ARM.

The anterior and posterior borders of the **deltoid** may be traced from the shoulder girdle to the insertion of that muscle. The surface relations of the anterior border have already been referred to; the posterior border forms a well-marked and important landmark as it crosses the angle between the axillary border of the scapula and the upper part of the shaft of the humerus. By making an incision along this part of the posterior border of the deltoid, and retracting the edge of the muscle upwards and outwards, we expose the **surgical neck** of the **humerus,** the quadrilateral opening in the posterior wall of the axilla transmitting the posterior **circumflex artery** and the **circumflex nerve**; a little lower down is the musculo-spiral nerve. The **coraco-brachialis,** the guide to the upper half of the brachial artery, forms a prominence occupying the upper half of the *internal bicipital furrow.* Traced downwards the internal bicipital furrow widens out into an elongated triangle. This triangle, which may be termed the *internal supracondyloid triangle,*

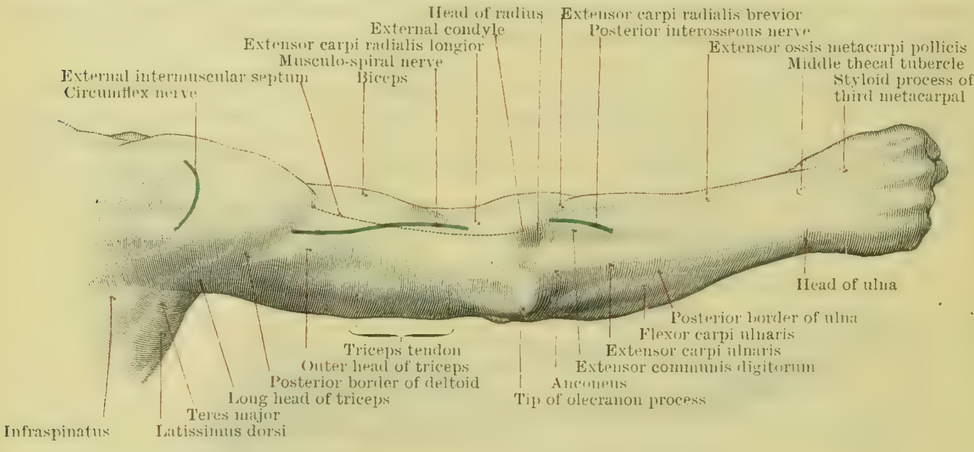

FIG. 810.—EXTENSOR ASPECT OF UPPER LIMB.

becomes continuous below with the inner part of the triangle in front of the bend of the elbow, and is limited posteriorly by the internal intermuscular septum, which may be felt as a cord-like band extending upwards from the internal condyle; the floor of the space is formed by the inner part of the brachialis anticus. Within the triangle are the following important structures, enumerated from without inwards, viz.: the **brachial artery,** the **median nerve,** the **lower part of the basilic vein,** the **internal cutaneous nerve,** and the **supracondyloid lymphatic glands,** two or three in number. Extending upwards from the external condyle to the insertion of the deltoid is the external intermuscular septum, which is pierced at the junction of its upper and middle thirds by the **musculo-spiral nerve.** Between the external intermuscular septum and the outer edge of the biceps is the ill-defined *external bicipital furrow,* the floor of which is formed by a strip of the brachialis anticus, and, nearer the elbow, by the supinator longus and extensor carpi radialis longior.

The posterior compartment of the upper arm is occupied by the **triceps,** the *long head* of which can be traced upwards to the axillary border of the scapula in front of the posterior border of the deltoid and behind the posterior fold of the axilla. The *outer head* of the triceps, after emerging from under cover of the lower part of the posterior border of the deltoid, is continued obliquely down the outer aspect of the upper arm as a well-marked muscular elevation. Above the olecranon is the strap-like tendon of insertion of the triceps, which, when the elbow is fully flexed, forms an admirable posterior splint in supracondyloid fractures of the humerus.

The **brachial artery,** slightly overlapped in the upper half of the arm by the coraco-brachialis and in the lower half by the biceps, can be felt pulsating throughout the whole length of the anterior part of the internal bicipital furrow. The

course of the vessel may be mapped out upon the surface by drawing a line from the inner border of the coraco-brachialis, at the level of the posterior fold of the axilla, downwards to a point (opposite the neck of the radius) $\frac{1}{2}$ in. below the middle of the bend of the elbow. In ligaturing the vessel, the edges of the coraco-brachialis and biceps muscles, together with the median nerve, furnish valuable guides to the artery, the mobility of which is often a source of trouble in performing the operation.

The **basilic vein**, which is superficial to the deep fascia in the lower third of the upper arm, is visible in the internal supracondyloid triangle and the lower part of the internal bicipital groove. The **cephalic vein** ascends a little internal to the outer edge of the triceps to reach the interval between the deltoid and pectoralis major.

The surface guide for the **median nerve** is the same as that for the brachial artery. The **ulnar nerve** is indicated superficially by a line extending from the outer wall of the axilla immediately behind the prominence of the coraco-brachialis, to the back of the internal condyle; in the upper half of the arm the nerve lies close behind the brachial artery under cover of the basilic vein, while in the lower half it lies a little behind the internal intermuscular septum, partially embedded in the fibres of the inner head of the triceps. To map out the course of the **musculo-spiral nerve**, first mark the point where it pierces the external intermuscular septum, viz. the junction of the upper and middle thirds of a line extending from the insertion of the deltoid to the external condyle; from this point draw a line obliquely downwards and forwards to the front of the external condyle, where the nerve divides into its radial and posterior interosseous branches. To map out the nerve as it lies in the musculo-spiral groove, draw a line from the same point obliquely upwards across the prominence formed by the outer head of the triceps to the junction of the posterior fold of the axilla with the upper arm. In fractures of the humerus in the neighbourhood of the insertion of the deltoid, the nerve is not infrequently lacerated, or so involved in the callus as to produce the condition known as "*drop-wrist*," the result of paralysis of the extensor muscles of the forearm. To cut down upon the nerve, commence the incision a little below the point where it pierces the external intermuscular septum, and carry it obliquely upwards and slightly backwards through the outer head of the triceps.

The **shaft** of the **humerus**, nowhere subcutaneous, is most readily manipulated in the region of the insertion of the deltoid, upwards along the outer head of the triceps, and downwards behind the external supracondyloid ridge. The **surgical neck**, situated between the tuberosities and the attachments of the muscles inserted into the region of the bicipital groove, is related to the outer wall of the axilla, and is on a level with the junction of the upper and middle thirds of the deltoid; at the same level are the circumflex vessels and nerves.

The shaft may be cut down upon with least injury to soft parts: (1) in its *upper third, anteriorly*, by an incision extending downwards through the anterior fibres of the deltoid, parallel, and a little external, to the bicipital groove; the sheath of the biceps will thus be avoided, and the small anterior circumflex artery will be the only vessel divided. (2) In the *upper third, posteriorly*, by an incision through the posterior fibres of the deltoid, the bone being reached just external to the origin of the outer head of the triceps, thus avoiding the musculo-spiral nerve; the circumflex vessels and nerves will be exposed at the upper part of the wound. (3) In the *lower third*, by an incision extending upwards from the back of the external condyle a little to the inner side of the external intermuscular septum.

THE ELBOW.

In injuries about the elbow the diagnosis rests mainly upon the relative positions of the bony points, which are, therefore, of great importance. The **epicondylar processes** of the humerus are both subcutaneous and upon the same level, the internal being the more prominent. In the extended position of the elbow the tip of the **olecranon** is on a level with a line joining the epicondyles; when the forearm is flexed the olecranon descends, and when full flexion is

reached it lies 1 in. below the condyles, and in a plane anterior to the posterior surface of the lower end of the humerus. The **head** of the **radius**, which lies nearly 1 in. below the external epicondyle, is best manipulated from behind by placing the thumb upon it, while the semi-flexed forearm is being alternately pronated and supinated. Upon the outer part of the posterior aspect of the extended elbow is a distinct dimple, which overlies the **radio-humeral articulation**; this dimple, along with the hollows on either side of the olecranon, becomes effaced in synovial thickenings and effusions into the joint. The **coronoid process** is situated too deeply to be distinctly felt. The **lower epiphysis** of the humerus includes the articular portion of the lower extremity and the external condyle; it is, therefore, small and almost entirely intra-articular, so that foci of disease in its neighbourhood soon invade the cavity of the joint. The internal epicondyle ossifies as a

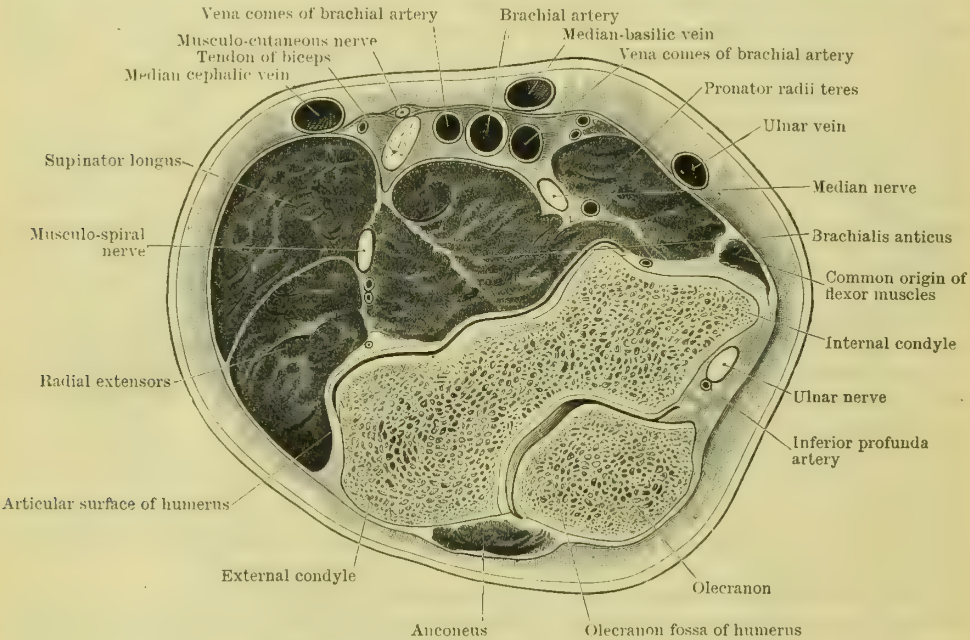

FIG. 811.—TRANSVERSE SECTION THROUGH THE BEND OF THE ELBOW.

separate epiphysis which unites with the lower end of the diaphysis. In the commonest dislocation of the elbow, viz. with backward displacement of both bones of the forearm, the normal relative position of the bony points is lost, whereas in a transverse supracondyloid fracture the normal relations are maintained. In the child the head of the radius is relatively smaller, and less firmly kept in position by the orbicular ligament than in the adult, so that it is liable to be partially dislocated, giving rise to the condition known as "*pulled elbow.*" To evacuate pus from the elbow-joint a vertical incision should be made over the dorsal aspect of the joint, immediately external to the olecranon.

The **median vein** is seen to bifurcate into median basilic and median cephalic ½ in. below the middle of the bend of the elbow; opposite the same point, but beneath the deep fascia, is the **bifurcation** of the **brachial artery**. The **median basilic** and **median cephalic** veins diverge as they ascend one on either side of the biceps tendon; the larger of the two veins, viz. the median basilic, is usually selected for the operations of venesection and transfusion. When the elbow is flexed the **biceps tendon** can be traced vertically through the centre of the bend of the elbow almost to its insertion. Passing downwards and inwards from the inner edge of the tendon is the **bicipital fascia**, which separates the median basilic vein from the brachial artery. If the finger nail be insinuated beneath the inner edges of the fascia the point of the finger will rest upon, and feel the pulsations of, the brachial artery. The **median nerve** descends through the space a little internal to the brachial artery. The bifurcation of the **musculo-spiral nerve** takes place in front of the external condyle

under cover of the supinator longus. The **ulnar nerve** can be rolled beneath the finger upon the back of the internal condyle: its position renders it liable to injury in severe fractures about the elbow, and in excising the joint care must be taken not to injure the nerve.

THE FOREARM AND HAND.

The upper half of the **radius** is deeply placed; the lower half is, however, easily palpated. The anterior border of its lower extremity is felt as a prominent transverse ridge, situated 1 in. above the thenar eminence: immediately below the ridge is the **radio-carpal articulation.** The **tip** of the **styloid process**, situated nearly ½ in. lower than that of the ulna, is deeply placed at the outer side of the wrist, in the hollow between the extensor tendons of the first and second phalanges of the thumb. Upon the middle of the posterior surface of the lower end of the radius is the **dorsal radial tubercle** which intervenes between the extensor of the second phalanx of the thumb and the short radial extensor of the wrist; the tubercle can be distinctly felt, and may be taken as a guide to the upper end of Lister's dorso-radial incision for excision of the wrist. The posterior border of the ulna is subcutaneous throughout, and may be felt along the interval between the flexor and extensor carpi ulnaris muscles. Upon the ulnar side of the dorsal aspect of the wrist is a well-marked rounded prominence formed by the **lower extremity** of the **ulna**, anterior to which is the **styloid process**, the deep groove between the two being occupied by the tendon of the extensor carpi ulnaris.

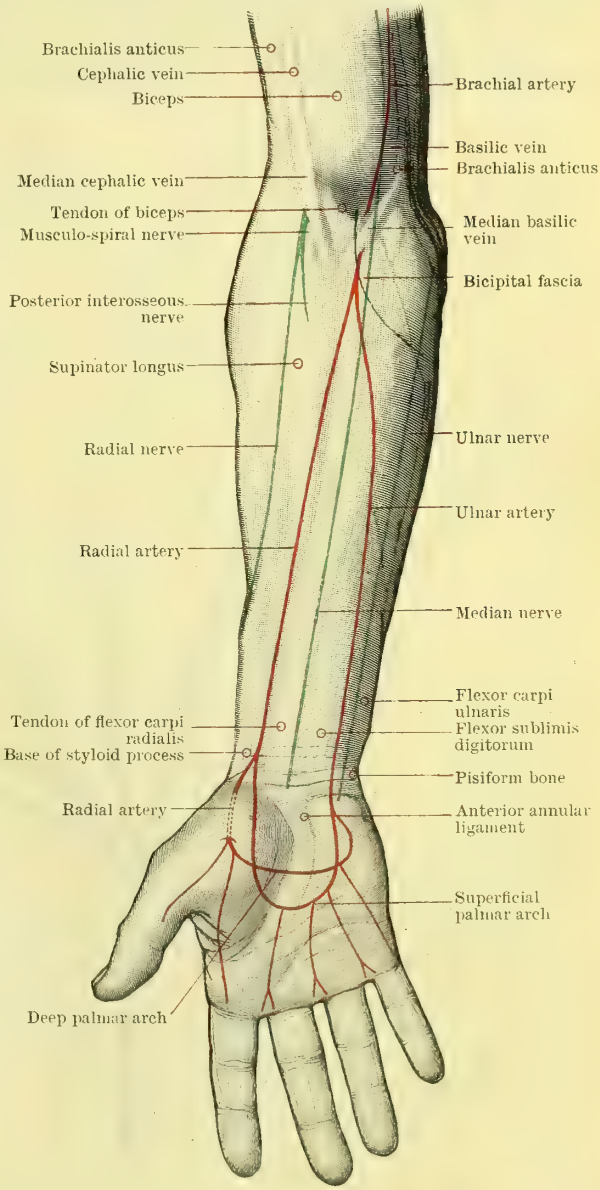

FIG. 812.—BEND OF ELBOW, FRONT OF FOREARM, AND PALM OF HAND.

The **carpal bones** are built up so as to form an arch, converted by the **anterior annular ligament** into a tunnel for the transmission of the flexor tendons. At each extremity of the arch the two bony points to which the ligament is attached furnish important landmarks. These bony points are: *externally*, the tubercle of the scaphoid and the ridge of the trapezium; *internally*, the pisiform and the hook of the unciform. The **tubercle** of the **scaphoid** is felt immediately above the root of the thenar eminence, midway between the tendons of the extensor ossis metacarpi pollicis and the flexor carpi radialis; ½ in. below the tubercle of the scaphoid is the **ridge** of the **trapezium**, felt deeply beneath the inner part of the thenar eminence. At the root of the hypothenar eminence, and crossed by the crease

which separates the forearm from the hand, is the **pisiform bone**, above which is the tendon of the flexor carpi ulnaris, passing to be inserted into it. The **hook** of the **unciform** is felt deeply beneath the radial side of the hypothenar eminence, and a full finger's breadth below and external to the pisiform.

The bases of the **first**, **third**, and **fifth metacarpals**, all of which can be readily identified on the dorsal aspect, furnish a sufficient guide to the line of the carpo-

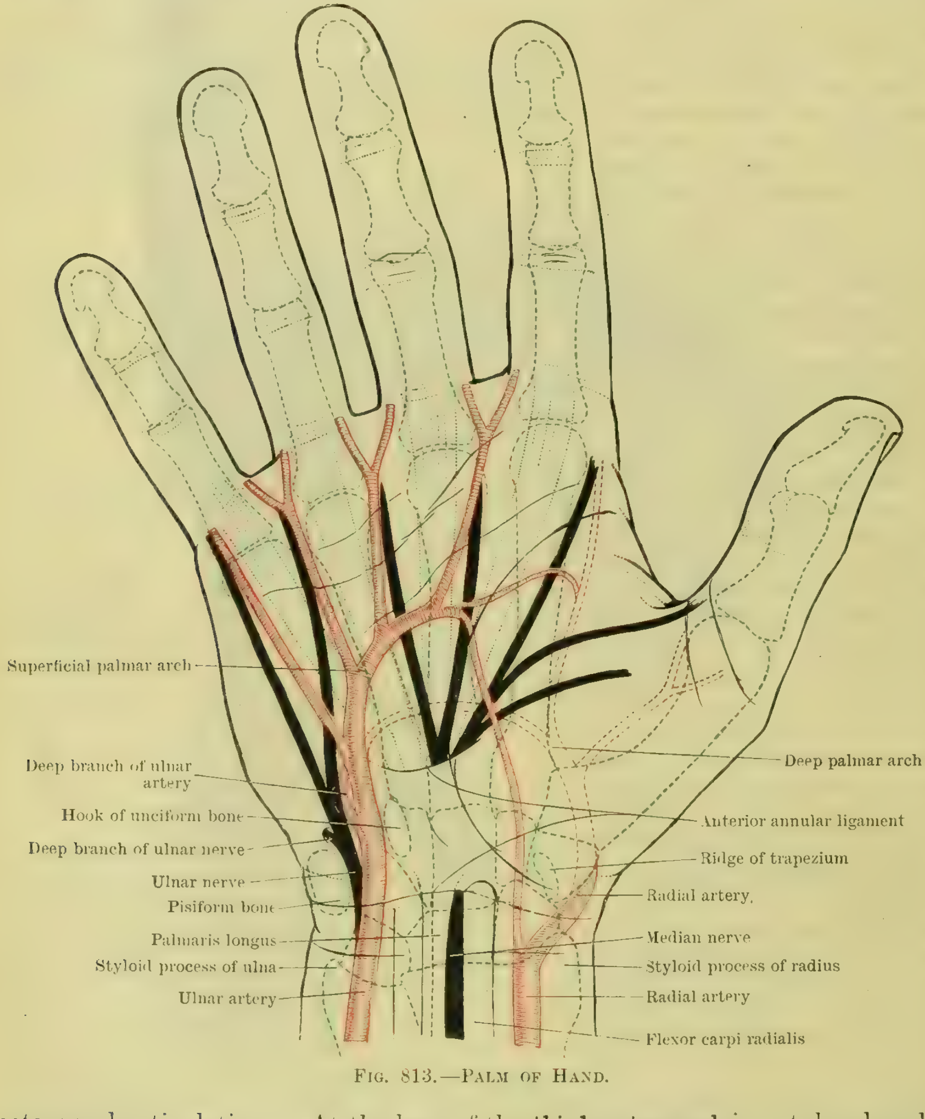

FIG. 813.—PALM OF HAND.

metacarpal articulations. At the base of the **third metacarpal** is a tubercle, which can be felt projecting from its dorsal aspect at a point $1\frac{3}{4}$ in. vertically below the tubercle upon the back of the lower end of the radius. This metacarpal tubercle marks the insertion of the extensor carpi radialis brevior, the favourite site for the development of a "*ganglion*," which may frequently be ruptured by pressing it firmly against the tubercle. Anteriorly, the carpo-metacarpal articulations correspond to the lower border of the anterior annular ligament.

The *prominences* of the *knuckles* are formed entirely by the heads of the metacarpal bones. Anteriorly, the **metacarpo-phalangeal articulations** are situated $\frac{3}{4}$ in. above the level of the web of the fingers; posteriorly, the joints may be felt as a groove immediately above the projecting ridge at the base of the first phalanges. A well-marked crease crosses obliquely over the anterior aspect of the metacarpo-phalangeal joint of the thumb. To cut into the **first interphalangeal**

joints from the front, incise along the *highest* of the creases in front of the joints; whereas to cut into the **terminal joints,** incise along the *lowest* of the creases in front of the joints. Posteriorly, the first and terminal interphalangeal articulations are opposite the distal of the various creases overlying the joints.

The most important *muscular* landmarks upon the front of the forearm are the supinator longus, the flexor carpi radialis and the pronator radii teres. The

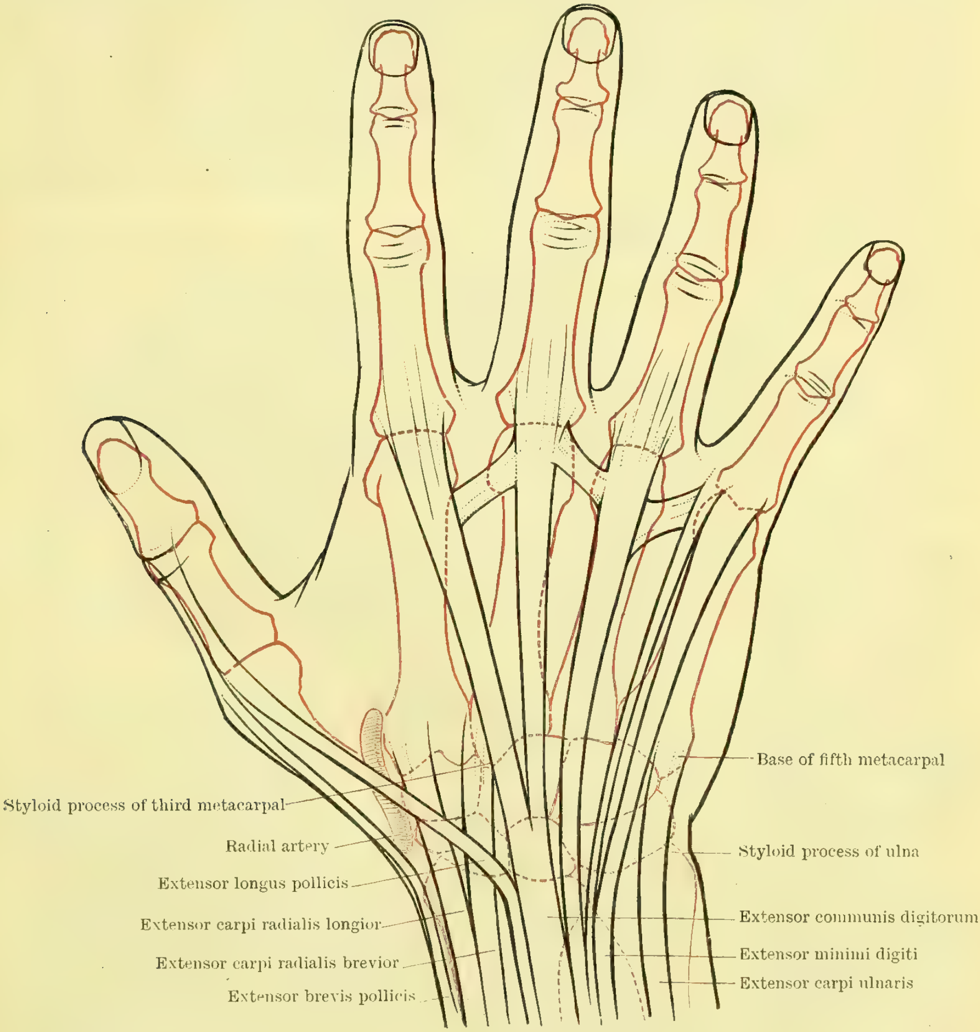

FIG. 814.—DORSAL ASPECT OF HAND.

supinator longus is thrown into prominence by flexing the semi-prone forearm against resistance. At the junction of the upper and middle thirds of the forearm the **pronator radii teres** passes beneath the supinator longus; between the two is the radial artery. The tendon of the **flexor carpi radialis** forms a prominent landmark descending along the middle of the anterior aspect of the forearm towards the ridge of the trapezium; the tendon of the **palmaris longus,** when present, is seen to its inner side.

At the back of the forearm the intermuscular septum between the radial and common extensors corresponds to the upper part of a line extending from the external epicondyle of the humerus to the tubercle on the back of the lower end of the radius. The **posterior interosseous nerve,** at the point at which it emerges from the substance of the supinator brevis, will be found at the bottom of this septum, 2 in. below the head of the radius; below this point the septum is the best line along which to cut down upon the posterior surface of the radius. Winding across

the lower third of this surface is an oblique prominence caused by the extensors of the metacarpal bone and first phalanx of the thumb.

The flexor sheaths of the palm and of the digits are of surgical importance in consequence of their liability to suppurative inflammation. The **common flexor sheath** begins $1\frac{1}{2}$ in. above the annular ligament, under which it extends to a little below the middle of the palm. The **digital flexor sheaths** extend from the bases of the terminal phalanges to the level of the distal transverse crease of the palm, opposite the necks of the metacarpal bones, *with the exception of the sheath of the little finger*, which is continuous with the common flexor sheath of the palm. The **sheath of the flexor longus pollicis** extends from the base of the terminal phalanx upwards to a point about 1 in. above the annular ligament; it frequently communicates with the common flexor sheath. From this anatomical arrangement it follows that suppuration in the sheaths of the little finger and thumb is specially liable to spread upwards into the palm, and thence underneath the annular ligament into the forearm.

The pulsations of the **radial artery** can readily be felt in the lower third of the forearm, midway between the outer border of the radius and the tendon of the flexor carpi radialis. The course of the vessel is indicated upon the surface by a line extending from the bifurcation of the brachial ($\frac{1}{2}$ in. below the middle of the bend of the elbow) to the tubercle of the scaphoid, around which, and below the tip of the styloid process, the artery winds to the back of the radial side of the wrist; in the latter situation the vessel, after passing beneath the extensor tendons of the thumb, dips into the palm through the proximal extremity of the first interosseous space. Incisions for opening or resecting the wrist are planned so as to avoid the vessel.

The upper third of the **ulnar artery** is deeply placed, and takes a curved course from the bifurcation of the brachial towards the inner part of the anterior surface of the forearm; the lower two-thirds of the vessel correspond to the lower two-thirds of a line drawn from the front of the internal condyle to the inner border of the pisiform bone. The course of the **ulnar nerve** corresponds to the whole of the above line.

The **median nerve** in the forearm may be mapped out by a line extending from a point midway between the centre of the bend of the elbow and the internal epicondyle, to a point midway between the styloid processes; in the lower third of the forearm the line follows the inner border of the tendon of the flexor carpi radialis. To evacuate pus spreading deeply up the front of the forearm, the incisions should be made on either side of the line corresponding to the median nerve. The **radial nerve** winds to the back of the forearm round the outer border of the radius beneath the tendon of the supinator longus, at the junction of the middle and lower thirds of the forearm. The summit, or most distal part of the **superficial palmar arch**, corresponds to the mid-point of a line extending from the middle of the lowest transverse crease of the wrist to the root of the middle finger; a line drawn from the outer border of the pisiform bone across the hook of the unciform, and thence in a curved direction downwards and outwards to this point, corresponds to the main or proximal part of the arch: the first and fourth digital branches overlie the fifth and third metacarpal bones respectively, while the second and third overlie the fourth and third interspaces respectively. The **deep arch** lies almost transversely, midway between the lower border of the anterior annular ligament and the superficial arch. The **radialis indicis** corresponds to the radial border of the index-finger.

The **ulnar nerve** and the commencement of its two divisions lie immediately to the inner side of the superficial palmar arch, so that the pisiform and the hook of the unciform are the guides to the nerve. The **median nerve** emerges from beneath the annular ligament opposite the inner edge of the thenar eminence, while the digital branches to the thumb follow its lower margin. Incisions for the removal of foreign bodies may therefore be made into the thenar with greater freedom than into the hypo-thenar eminence.

Incisions to evacuate deep-seated pus in the palm may be made in one or more of the following situations: (1) over the lower two-thirds of the second metacarpal bone; (2)

over the distal half of the fourth metacarpal bone; (3) from the proximal part of the first incision an opening may be made through the first interosseous space on to the dorsum, care being taken to keep below the radial artery; (4) a longitudinal incision between the median and ulnar nerves, on the proximal side of the superficial palmar arch. At the wrist a longitudinal incision may be made immediately internal to the palmaris longus tendon, thus falling between the line of the median nerve and the ulnar artery. To open the **digital flexor sheaths**, incisions are made along the middle of the palmar surface of the fingers opposite the first and second phalanges. The **collateral digital vessels** and **nerves** descend along the lateral aspects of the fingers, nearer the flexor than the extensor surfaces. In cutting down upon the dorsal aspects of the phalanges, the incisions should be made to one or other side of the extensor tendon, preferably upon the ulnar side, to avoid division of the insertions of lumbrical muscles. The subcutaneous tissue of the palmar aspect of the terminal phalanges is connected by fibrous processes with the periosteum; hence the frequency of necrosis of the terminal phalanx in suppurative inflammations in this region.

THE LOWER EXTREMITY.

THE BUTTOCK.

The region of the hip or buttock extends from the crest of the ilium above to the gluteal fold below. The highest point of the **iliac crest**, situated a little behind its middle, is on a level with the fourth lumbar spine; the **anterior superior spine** of the **ilium** is directed forwards, and belongs to the groin, which it limits externally; the **posterior superior spine**, situated at the bottom of a dimple or small depression, is on a level with the second sacral spine, and corresponds, therefore, to the middle of the **sacro-iliac joint**. Two and a half inches behind the anterior superior spine is a prominence upon the outer lip of the iliac crest; this prominence, which is termed the **tubercular point**, is the most external part of the crest, and will be again referred to in dealing with the surface anatomy of the abdomen. A hand's breadth below the tubercle of the crest is the **great trochanter** of the femur, the most external bony landmark of the hip; its anterior and posterior borders are best felt between the fingers and thumb, while the limb is slightly abducted to relax the ilio-tibial band, and if the thigh be now rotated, it will be noted that the trochanter rotates around the segment of a circle, the radius of which is formed by the head and neck of the femur; in non-impacted fractures of the neck of the femur the trochanter rotates around the segment of a much smaller circle. *Nelaton's line*, drawn from the anterior superior spine to the most prominent part of the ischial tuberosity, crosses the hip at the level of the upper border of the great trochanter; this line is employed to ascertain the presence or absence of upward displacement of the trochanter. Chiene demonstrates the relative height of the trochanters by stretching two tapes across the front of the pelvis, one between the anterior superior spines, and the other between the upper borders of the trochanters; the lower tape will converge towards the upper on the side of the upward displacement. A line prolonging the anterior border of the great trochanter vertically upwards touches the iliac crest at the tubercular point. The **ischial tuberosity**, in the erect posture, is overlapped by the lower border of the gluteus maximus; its most prominent part is felt a little above the inner part of the gluteal fold. If the hip be rotated inwards, the **lesser trochanter** of the femur may be felt by deep palpation above the outer end of the gluteal fold; it corresponds to the interval between the lower border of the quadratus femoris and the upper border of the adductor magnus, and therefore, also, to the level of the internal circumflex artery.

The **lower border** of the **gluteus maximus** lies a little above the **gluteal fold** internally, crosses it about its middle, and is continued downwards and outwards to meet the upper end of the furrow of the external intermuscular septum, at the junction of the upper and middle thirds of the femur. The inner borders of the two great gluteal muscles are separated by the deep **gluteal cleft**, which extends upwards and backwards from the perineum to the level of the fourth sacral spine, where it opens out into the triangle upon the back of the sacrum. Anteriorly the buttock is limited by the prominence of the **tensor fasciæ femoris muscle**, which

extends downwards and somewhat backwards from the anterior end of the crest, to join the ilio-tibial band below the root of the great trochanter.

The **gluteal artery** reaches the buttock immediately below the upper border of the great sacro-sciatic foramen, opposite a point corresponding to the junction of the upper and middle thirds of a line drawn from the posterior superior iliac spine to the upper border of the great trochanter. To expose the vessel, the incision should be made along this line, which has the advantage of running parallel to the fibres of the gluteus maximus, as well as parallel to the interval between the gluteus medius and pyriformis muscles.

The **great sciatic nerve** enters the buttock at a point corresponding to the junction of the upper and middle thirds of a line drawn from the posterior superior iliac spine to the ischial tuberosity; from this point the nerve passes downwards and slightly outwards upon the ischium to a point midway between its tuberosity and the great trochanter. The **spine of the ischium** and the **pudic vessels** are situated opposite the junction of the lower and middle thirds of the above line. The vessels and nerves which enter the buttock through the great sacro-sciatic foramen *below the pyriformis*, may be exposed through an incision below and parallel to that above described for exposing the gluteal artery, viz. an incision corresponding to the middle two-fourths of a line extending from the upper end of the gluteal cleft to the root of the great trochanter; the deep landmarks are the lower border of the pyriformis and the root of the ischial spine.

THE BACK OF THE THIGH.

The **hamstring muscles**, and especially the tendon of the biceps and semitendinosus, are thrown into prominence either by standing on tiptoes with the

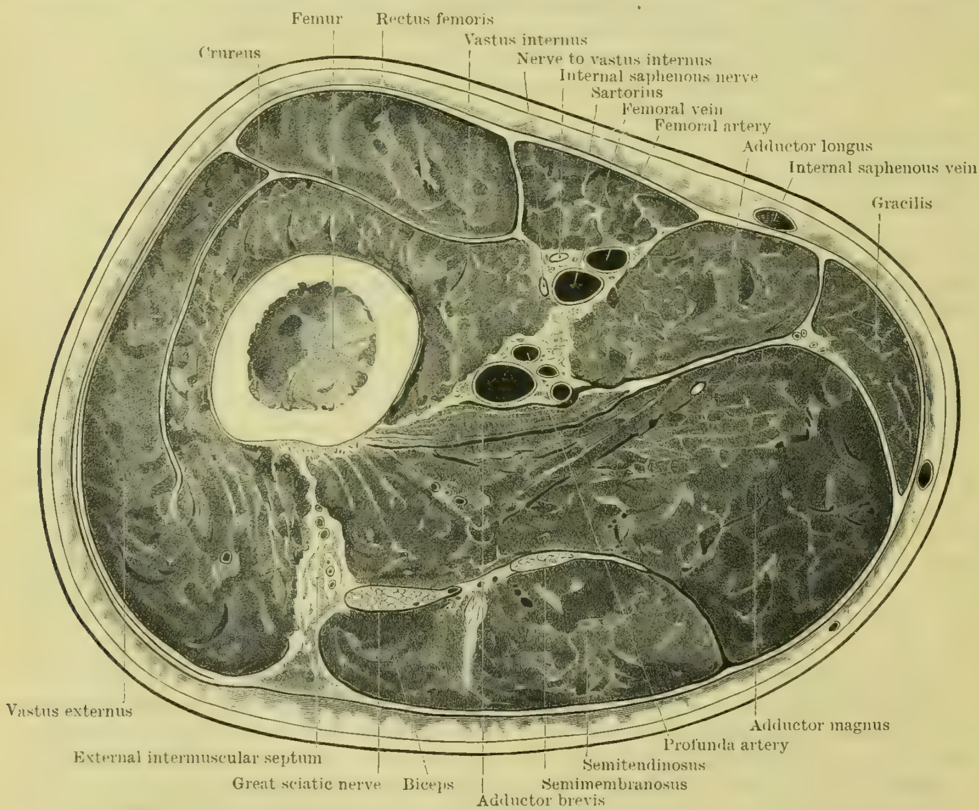

FIG. 815.—SECTION THROUGH THIGH AT THE LEVEL OF THE UPPER PART OF HUNTER'S CANAL.

knees slightly flexed, or by flexing the leg against resistance. By throwing the hamstrings into action, the line of the external intermuscular septum of the thigh is

indicated by a well-marked furrow, extending from the lower edge of the insertion of the gluteus maximus to the outer aspect of the knee; behind this furrow is the **biceps**, and in front of it is the large **vastus externus**, covered by the strong ilio-tibial portion of the fascia lata. The **shaft of the femur** may be cut down upon along the whole length of this furrow with least injury to the soft parts; the trigone of the femur and deep-seated popliteal abscesses are most conveniently reached through the lower part of the same incision. The course of the **great sciatic nerve** corresponds to the upper half of a line extending from a point midway between the tuberosity of the ischium and the great trochanter to the centre of the popliteal space. The nerve enters the thigh under cover of the outer border of the biceps, whereas the **small sciatic**, which takes the same line, descends superficial to the biceps, between it and the fascia lata. In the operation of stretching the great sciatic the nerve is cut down upon immediately below the lower border of the

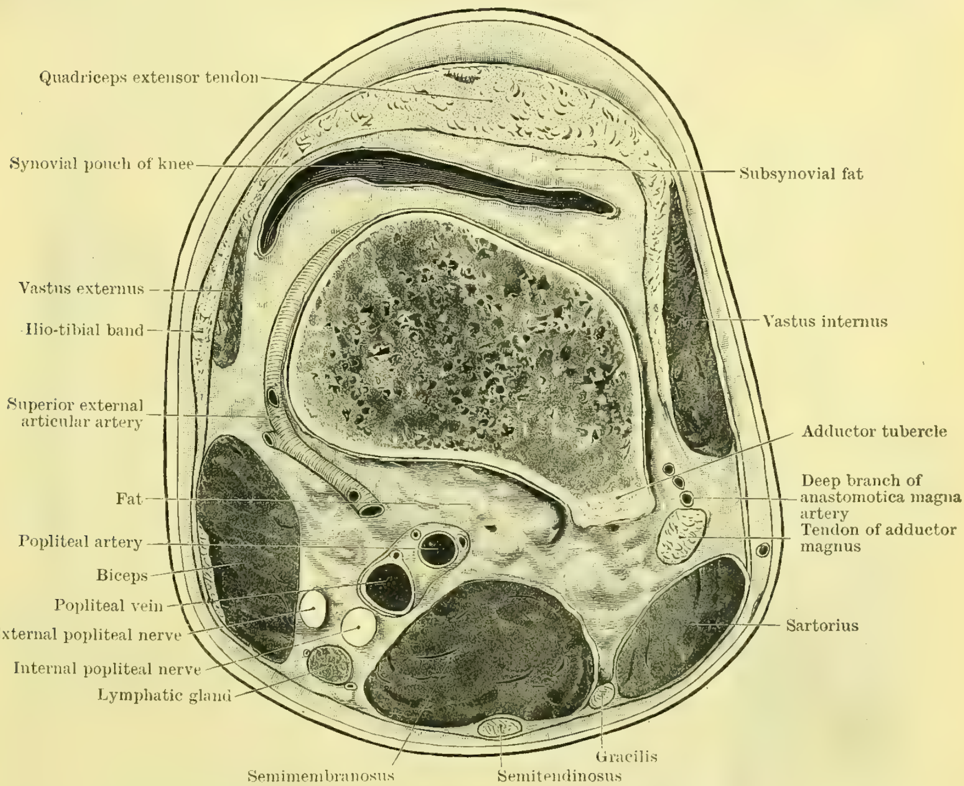

FIG. 816.—SECTION THROUGH THE THIGH IMMEDIATELY ABOVE THE PATELLA.

gluteus maximus. The surgeon, standing on the side of the patient opposite to the leg to be operated upon (Chiene), makes an incision in the line of the nerve through the integuments and fascia lata, and, sweeping the index-finger round the outer border of the biceps, hooks up the nerve as it lies between that muscle and the adductor magnus. The **external popliteal nerve** may be rolled under the finger as it descends immediately behind the tendon of the biceps and the head of the fibula; so close is the nerve to the tendon that the latter should be divided, in cases where this is necessary, by the open method, rather than subcutaneously.

Abscesses may reach the flexor compartment of the thigh from various sources, viz.: (1) from the posterior aspect of the hip-joint; (2) from the pelvis through the great sacro-sciatic foramen; (3) from one or other of the bursæ under the gluteus maximus; (4) from the front of the hip-joint by passing backwards under the tensor fasciæ femoris; or by winding backwards beneath the neck of the femur, and through the interval between the quadratus femoris and the adductor magnus; (5) from the iliac fossa under Poupart's ligament into Scarpa's triangle, and thence to the back of the thigh by one or other of the routes already mentioned; (6) the pus may spread upwards from the trigone of the femur, the knee, a popliteal gland, or from a bursa.

THE POPLITEAL SPACE.

When the knee is extended the **popliteal fascia** is put upon the stretch, and obliterates the hollow of the popliteal space; by flexing the knee the fascia is relaxed, and the fingers may be pressed deeply into the upper or femoral division of the space; as a rule, the pulsations of the popliteal artery can be felt. Beneath the **semitendinosus** is the fleshy **semimembranosus**, which bulges into the space and overlaps the upper part of the popliteal artery. Between the semimembranosus and the inner head of the gastrocnemius is the most important **bursa** in the popliteal region; it not infrequently becomes distended with fluid, and then presents usually a more or less sausage-shaped outline; according to Holden, the bursa communicates with the cavity of the knee-joint in one subject out of five.

To map out the line of the **popliteal vessels** and the **internal popliteal nerve**, draw a line from a point a little internal to the upper angle of the space to a point mid-

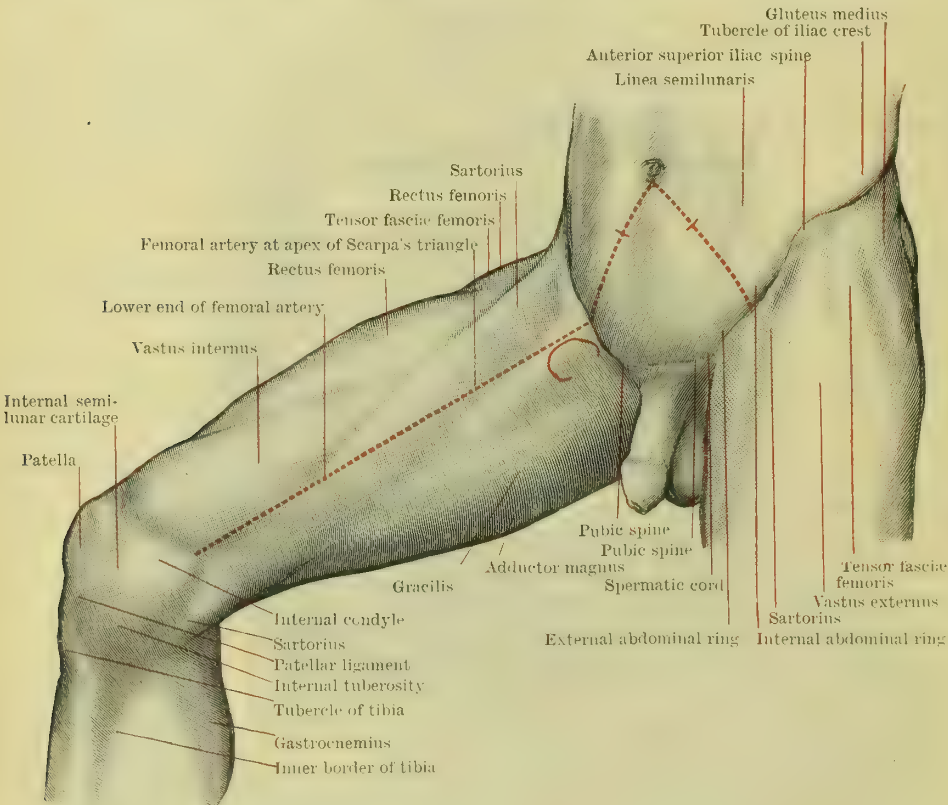

FIG. 817.—THE THIGH AND GROIN.

way between the condyles of the femur, and thence down the middle of the space to the level of the lower part of the tubercle of the tibia. The internal popliteal nerve lies immediately beneath the deep fascia; the artery is separated from the trigone of the femur by a quantity of fat. The popliteal **lymphatic glands** lie beneath the popliteal fascia, one upon the internal popliteal nerve, the others deeply in the space (Leaf).

THE FRONT OF THE THIGH.

Between the front of the thigh and the abdomen is the *fold of the groin*, at the bottom of which **Poupart's ligament** can be felt as a tense band, stretching from the anterior superior spine of the ilium to the spine of the pubis. The **anterior superior spine** looks directly forwards; comparative measurements of the lower extremities

are made by stretching a tape from it to the tip of one or other of the malleoli, care being taken that the pelvis is horizontal, and the limbs in corresponding positions. The **pubic spine** is felt under the upper and outer part of the mons Veneris and at a corresponding point in the male; between the spine and the symphysis is the **crest** of the pubis, the two crests together forming a rounded subcutaneous bony ridge. A line extending from the pubic spine horizontally outwards across the front of the thigh crosses the front of the hip-joint at the level of the lower part of the head of the femur. The cord-like **tendon** of the **adductor longus** is readily felt, and a point about 1 in. below the pubic spine is selected for performing the operation of subcutaneous tenotomy of the tendon.

The centre of the **saphenous opening** is situated $1\frac{1}{2}$ in. below and external to the pubic spine; it overlies the inner (hernial) and middle (venous) compartments of the femoral sheath; behind the outer border of the opening is the arterial compartment of the sheath; crossing over the lower border is the termination of the long saphenous vein. A femoral hernia makes its way into the thigh beneath the upper edge of the opening. The course of the **long saphenous vein** in the thigh is indicated by a line extending from the adductor tubercle of the internal condyle of the femur to the lower part of the saphenous opening.

The **horizontal** or **inguinal chain** of **lymphatic glands** can usually be felt along, and a little below, the line of Poupart's ligament; when the glands are inflamed the surgeon should not neglect to examine the buttocks and anus as well as the external genitals. The **vertical** or **femoral chain** lies in close relation to the upper end of the long saphenous vein. Deeper glands also are met with beneath the cribriform fascia, close to the inner side of the femoral vein, and there is generally one in the crural canal. To clear out the glands in the groin an incision should be made parallel to, and a finger's breadth below, the whole length of Poupart's ligament.

To map out the course of the **femoral artery**, the thigh being slightly flexed and rotated outwards, draw a line from the mid-point between the anterior superior iliac spine and the symphysis pubis to the adductor tubercle at the upper and back part of the internal condyle; rather less than the upper third of this line corresponds to the femoral artery in Scarpa's triangle, while rather more than its middle third corresponds to the artery as it lies in Hunter's canal. The seat of election for ligature of the vessel is at the apex of Scarpa's triangle. To compress the common femoral, pressure should be made directly backwards against the pubic eminence, and not against the head of the femur; to compress the femoral in Hunter's canal, pressure should be made outwards against the inner surface of the shaft of the femur.

On the outer aspect of the thigh the **fascia lata** is thick, aponeurotic, and loosely attached to the vastus externus; hence the tendency of abscesses to travel downwards beneath it towards the knee. The **sartorius**, which forms the most important muscular landmark of the thigh, may be thrown into prominence by maintaining the thigh unsupported, flexed, and slightly rotated outwards. Observe that in the upper third of the thigh it forms the outer boundary of Scarpa's triangle; in the middle third it is placed over Hunter's canal; while in the lower third it lies in front of the inner hamstrings. External and adjacent to the upper part of the sartorius is the prominence of the **tensor fasciæ femoris**, which, as it descends, diverges from the sartorius; in the angle between the two the tendon of the rectus may be felt as it overlies the lower part of the anterior aspect of the capsule of the hip-joint.

The inner aspect of the lower half of the **shaft of the femur** may be conveniently cut down upon through the vastus internus, where it comes to the surface between the sartorius and rectus muscles; the incision should be made in the direction of a line extending from a point midway between the inner border of the patella and the adductor tubercle, to the anterior superior iliac spine.

The front of the **hip-joint** may be reached through an incision downwards from the anterior superior iliac spine, either along the inner or the outer border of the sartorius; in the former case the deeper part of the dissection passes between the iliacus and the inner border of the rectus, while in the latter case the joint is reached external to the rectus tendon, between it and the anterior borders of the gluteus medius and minimus muscles. The ascending branch of the **external circumflex artery** crosses the capsule parallel to, and immediately above, the anterior

intertrochanteric line. The **ilio-psoas** crosses the anterior and the inner part of the capsule; between the two is a **bursa**, which frequently communicates with the joint through the thin part of the capsule internal to the ilio-femoral band; it is by way of this communication that a psoas abscess occasionally gives rise to secondary tubercular disease of the hip-joint. One of the commonest situations to meet with an abscess in hip-joint disease is in the cellular tissue and fat under the tensor fasciæ femoris; or the pus may pass below and to the inner side of the neck of the femur, and thence along the course of the internal circumflex artery to the back of the thigh. *To tap or explore the hip-joint*, the puncture should be made in the interval between the sartorius and the tensor fasciæ femoris, 2 to 3 in. below the anterior superior iliac spine; if the instrument is then pushed upwards, inwards, and backwards beneath the tendon of the rectus, it will pass through the capsule a little above the anterior intertrochanteric line. Regarded from the point of view of **dislocation**, the regions of the cotyloid notch and of the inferior part of the capsule are the weak points in the joint; it follows, therefore, that abduction favours dislocation by bringing the head of the femur into relation with these two weak areas.

THE KNEE.

With the knee extended and the quadriceps relaxed, the **patella** can be readily outlined and moved from side to side upon the femoral condyles. On contracting the quadriceps its tendon springs forwards and is felt as a tense band above the patella; while the **patellar ligament**, which has become tense and prominent, may be traced to the lower part of the tubercle of the tibia. In front of the lower part of the patella and of the upper part of the patellar ligament is the **pre-patellar bursa**, into which effusion takes place in the condition known as housemaid's knee. Beneath and on either side of the patellar ligament is a well-circumscribed pad of fat, palpation of which gives rise to a feeling closely resembling true fluctuation. In extension, only the lower pair of articular facets of the patella are in contact with the trochlear surface of the femur. In semiflexion the middle pair of facets rests upon the trochlea; in this position the inner margin of the internal condyle, the upper border of the inner tuberosity of the tibia, and the lower part of the patella are all distinctly visible, and together bound a triangular depression, which overlies the line of the joint and contains the anterior part of the **internal semilunar cartilage**: it is in this triangle that the surgeon searches for a displaced or thickened internal semilunar cartilage, for a loose body, and for "lipping" of the edge of the articular cartilage in chronic osteo-arthritis. A similar, but less well defined, triangle may be felt immediately external to the lower edge of the patella. When the quadriceps is thrown into sudden or violent contraction, as in preventing oneself from falling backwards, the patella may be transversely fractured at the

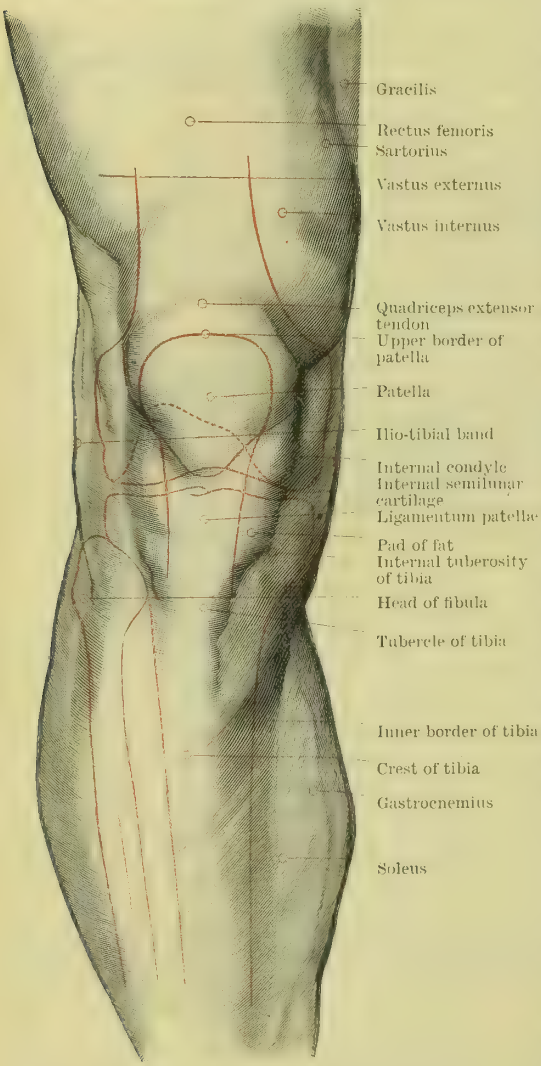

Fig. 818.—Anterior Aspect of Knee.

moment of partial flexion. In full flexion almost the whole of the trochlear surface of the condyles is exposed to palpation, covered, however, by the stretched quadriceps tendon.

The upper part of the inner surface of the internal condyle is overlapped by the muscular prominence of the lower fibres of the **vastus internus**. Leading upwards from the internal condyle is a slight furrow, corresponding to the interval between the lower part of the vastus internus and the sartorius; at the bottom of the furrow the cord-like **tendon of the adductor magnus** may readily be felt, and followed down to its insertion into the **adductor tubercle**; the latter, situated at the junction of the internal supracondyloid ridge with the upper and back part of the internal condyle, marks the level of the **epiphysial cartilage**. Anteriorly and posteriorly the epiphysial cartilage lies immediately above the highest part of the articular cartilage.

Disease of the lower end of the diaphysis of the femur generally invades the trigone of the femur and the popliteal space rather than the cavity of the knee-joint. In *Macewen's operation for knock-knee*, the incision (through which the osteotome is introduced to divide the femur) is carried down to the bone through the vastus internus a little above the internal condyle, a finger's breadth above the summit of the trochlea, to avoid injury to the epiphysial cartilage, and the same distance in front of the adductor tendon, to avoid injury to the deep branch of the anastomotic artery.

Below the internal condyle is the subcutaneous **inner tuberosity of the tibia** across which the tendons of the sartorius, gracilis, and semitendinosus pass to their insertion. Between the above tendons and the inner head of the gastrocnemius is a groove which winds downwards and forwards from the popliteal space; an incision along this groove will expose the **long saphenous vein** and **nerve** and the superficial branch of the anastomotic artery.

On the outer side of the knee is the **ilio-tibial band**, which, after crossing and obscuring the line of the joint, is attached to the **outer tuberosity of the tibia**. By semiflexion of the knee the posterior border of the band is thrown into relief, and a well-marked furrow intervenes between it and the prominent tendon of the biceps: the lower part of the shaft of the femur and the trigone may be reached through an incision along this furrow. Under cover of the ilio-tibial band, as it crosses the line of the joint, are the **external semilunar cartilage**, the **inferior external articular artery**, and the **external lateral ligament**. The **head of the fibula**, with the **tendon of the biceps** passing to be inserted into it, are rendered distinctly visible by semiflexing the knee; the former lies on a level with the tubercle of the tibia, 1½ in. behind and a little below the most prominent part of the outer tuberosity of the tibia. Immediately below the head of the fibula is the termination of the **external popliteal nerve**, which is liable to be contused from blows, and in fractures of the neck of the fibula.

The **synovial membrane** of the knee-joint extends downwards anteriorly as far as the level of the upper border of the tibia; posteriorly, it dips downwards for a short distance behind the popliteal notch of the tibia, to form a small cul-de-sac, the close relation of which to the popliteal artery must be borne in mind in performing the operation of excision of the knee. Anteriorly, the synovial cavity extends upwards beneath the quadriceps in the form of a pouch, which reaches nearly two inches above the articular surface of the femur; posteriorly, there is no extension of the synovial cavity upwards above the condyles; laterally, the synovial membrane covers the anterior third of the outer surface of each condyle.

In **effusion into the knee-joint** the hollows become obliterated, the patella is floated up, and fluctuation may be obtained above, below, and to either side of the patella.

To pass a tube through the knee-joint for drainage, two short vertical incisions should be made—one on each side of the joint at the level of the upper part of the patella, and a finger's breadth behind its lateral edges. In **arthrectomy** of the knee for tubercular disease, the subsynovial fat facilitates the separation of the suprapatellar pouch from the lower and anterior part of the shaft of the femur; to expose the **pouches behind the condyles**, the crucial ligaments must be divided.

THE LEG.

The inner surface of the **tibia** is subcutaneous throughout, hence the seat of a fracture of the shaft is, as a rule, easily felt, and the lower extremity of the upper

fragment is liable to perforate the skin. The skin over the lower half of this surface is the commonest seat of varicose and callous ulcers, which are frequently prevented from healing by adhesion of the floor of the ulcer to the periosteum.

The **shaft of the fibula**, situated on a plane posterior to that of the tibia, is, with the exception of the triangular subcutaneous surface above the external malleolus, deeply placed amongst the muscles. To examine the fibula, the surgeon should stand on the opposite side of the patient and manipulate the bone along the line of the intermuscular septum between the peronei and the muscles of the calf.

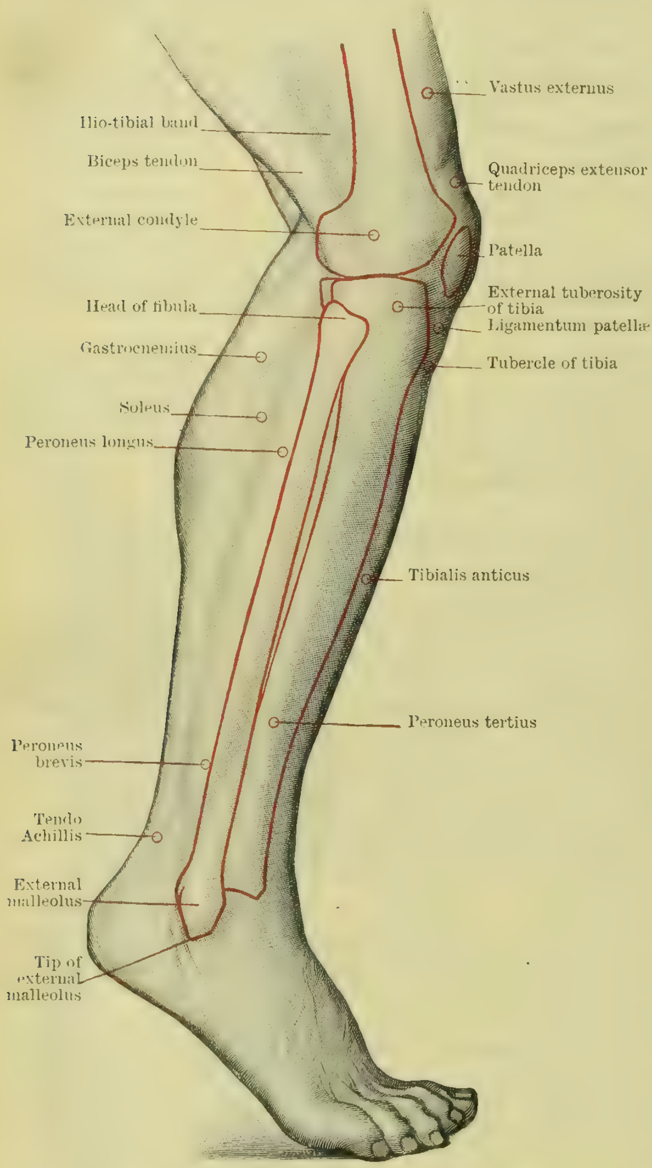

FIG. 819.—OUTER ASPECT OF KNEE AND LEG.

The greater fulness of the antero-external surface of the leg, as compared with its inner surface, is due to the presence of the **extensor** and **peroneal groups of muscles.** When these groups are thrown into action, the individual muscles are mapped out upon the surface by the grooves corresponding to their intermuscular septa. The **posterior peroneal septum** is seen as a well-marked furrow, extending from the posterior aspect of the head of the fibula to the hollow behind the external malleolus; in front of it are the **peronei muscles**, the *longus* giving rise to a prominence on the upper half of the leg, while the *brevis* is prominent on the lower half; behind the septum is a prominence formed by the outer border of the **soleus**, which projects beyond that of the **gastrocnemius.**

It is along the line of the posterior peroneal intermuscular septum that incisions should be made to expose the fibula; to avoid the musculo-cutaneous nerve, however, the incision must not extend higher than 1 in. below the head of the fibula.

The furrow between the extensors and the two peronei, the **anterior peroneal septum**, is much less distinct, and runs in a line from the anterior border of the head of the fibula to the anterior border of the external malleolus; the **cutaneous portion of the musculo-cutaneous** nerve corresponds to the lower half of this line. At the junction of the middle and lower thirds of the leg the extensor muscles incline inwards over the anterior surface of the tibia.

The **anterior tibial artery** reaches the front of the interosseous membrane 2 in. below the tubercle of the tibia; in the upper two-thirds of its course it lies upon the

interosseous membrane, while in its lower third it winds on to the front of the tibia, to terminate at a point opposite the ankle-joint, midway between the two malleoli. *Incisions to expose the vessel* should strike the outer border of the tibialis anticus, which corresponds to a line drawn from a point midway between the external tuberosity of the tibia and the head of the fibula, to the termination of the vessel.

When the muscles of the calf are thrown into action, a groove is seen between the two heads of the **gastrocnemius**, the fleshy fibres of which extend a little below the middle of the leg. The fleshy fibres of the **soleus** extend to the junction of the middle and lower thirds of the leg, and project beyond the margins of the gastrocnemius. The narrowest part of the **tendo Achillis** is situated opposite the bases of the malleoli, and it is here that the tendon is divided in the operation of tenotomy. The **short saphenous vein**, which lies a little to the outer side of the tendon, gradually reaches the middle of the calf, along which it ascends to the middle of the popliteal space. The **internal saphenous vein** and **nerve** lie along the inner border of the tibia.

The course of the **posterior tibial artery** is mapped out by drawing a line from the lower angle of the popliteal space, at the level of the lower border of the tubercle of the tibia, to a point midway between the internal malleolus and the tendo Achillis. *To expose the vessel* in the upper half of the leg, an incision is made parallel to and $\frac{1}{2}$ in. behind the inner border of the tibia; after retracting the inner border of the gastrocnemius and dividing the tibial origin of the soleus, the artery is found lying on the tibialis posticus. In exposing the artery below the soleus, divide two layers of deep fascia and keep the knife directed towards the tibia.

The **peroneal artery** is given off 3 in. below the head of the fibula; incisions to expose the vessel are made in the direction of a line extending from the posterior border of the head of the fibula to a point midway between the external malleolus and the tendo Achillis.

THE FOOT AND ANKLE.

The tip of the **external malleolus** is situated $\frac{1}{4}$ in. lower and $\frac{3}{4}$ in. further back than that of the **internal malleolus**. Above the external malleolus is the

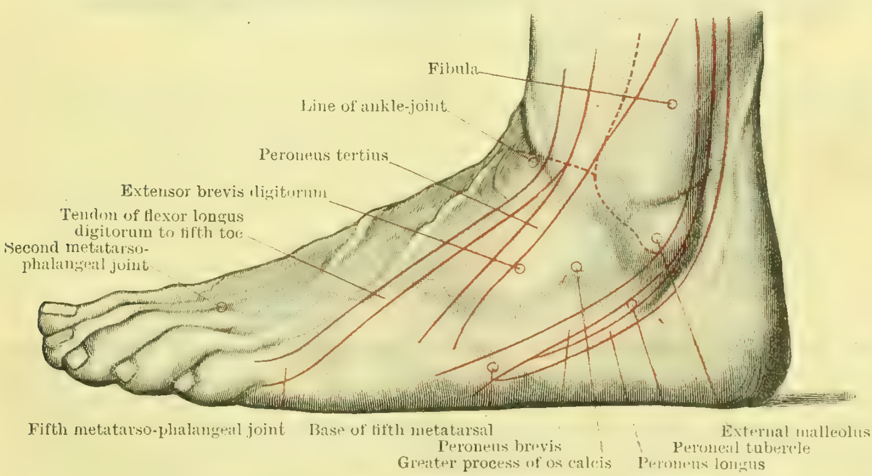

FIG. 820.—OUTER ASPECT OF FOOT AND ANKLE.

triangular subcutaneous surface of the fibula, the apex of which corresponds to the lower end of the extensor-peroneal intermuscular septum.

The **line of the ankle-joint** can be felt on either side of the extensor tendons, and when the foot is extended the anterior part of the superior articular surface of the **astragalus** forms a visible prominence below the anterior border of the lower end of the tibia. The small posterior surface of the astragalus is felt below and behind

the internal malleolus, at the anterior part of the hollow between it and the heel. In *effusions into the ankle-joint* the hollows in front and behind the malleoli are obliterated, and the extensor tendons are raised from the front of the joint.

A finger's breadth below the tip of the internal malleolus is the **sustentaculum tali**; $1\frac{1}{4}$ in. in front of the latter, and midway between the dorsal and plantar margins of the inner aspect of the foot, is the **tubercle of the scaphoid** (the inner landmark in Chopart's amputation), which is generally visible, and always distinctly palpable. The **calcaneo-astragaloid joint** lies immediately below the sustentaculum, while close above it the **tendon of the tibialis posticus** may be rendered visible, as it extends from behind the tip of the internal malleolus to the tubercle of the scaphoid. An inch and a half in front of the tubercle of the scaphoid is the **joint between the internal cuneiform and the first metatarsal**; the ridge at the base of the latter bone furnishes a good guide to the articulation. The first **metatarso-phalangeal joint** lies a little in front of the middle of the ball of the great toe.

A finger's breadth vertically below the tip of the external malleolus is the **peroneal tubercle** of the os calcis, and midway between the two is the **calcaneo-astragaloid joint**; the tubercle is, when present, a trustworthy guide to the level at which the **two peronei tendons** cross the outer surface of the os calcis. The **greater process** of the **os calcis** is felt in the triangular interval between the tendons of the

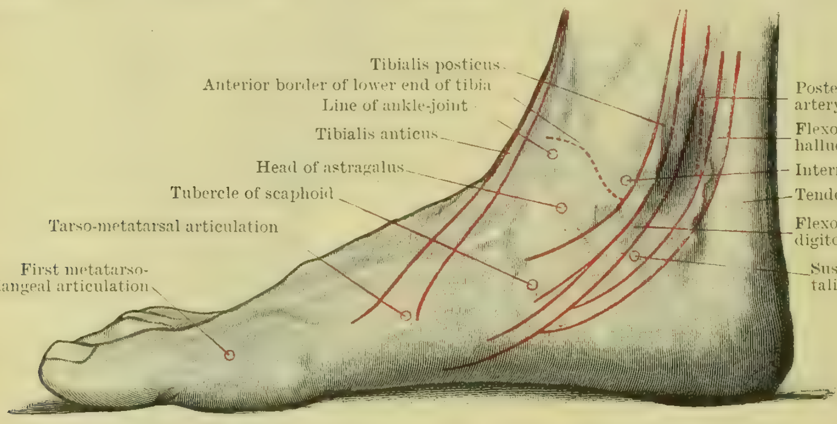

Fig. 821.—Inner Aspect of Foot and Ankle.

peroneus brevis and tertius; the **calcaneo-cuboid joint**—the outer landmark in Chopart's amputation—is placed a little in front of the mid-point between the tip of the external malleolus and the base of the fifth metatarsal bone. To open the **outer tarso-metatarsal articulations**, the knife, entered behind the projecting base of the fifth metatarsal bone, should be directed forwards as well as inwards. On the dorsum of the foot the tarsal joints are obscured by the extensor tendons. The **synovial membrane** of the **ankle-joint** is prolonged on to the neck of the astragalus, and care must be taken to avoid opening the ankle-joint in performing Chopart's amputation.

The **line** of the **tarso-metatarsal joints** extends nearly 1 in. further forwards on the inner than on the outer border of the foot; between these points the joint-line takes a zigzag course on account of the second metatarsal bone extending backwards between the internal and external cuneiform bones. The joint between the second metatarsal and middle cuneiform is nearly $\frac{1}{2}$ in. behind that between the first metatarsal and internal cuneiform, and nearly $\frac{1}{4}$ in. behind that between the third metatarsal and the external cuneiform. The strong transverse inter-osseous ligament (*Lisfranc's ligament*), which connects the outer surface of the internal cuneiform with the base of the second metatarsal, must be divided in the tarso-metatarsal amputation of Lisfranc. In order to preserve the insertions of the two tibial and the three peroneal muscles it is advisable, when possible, instead of disarticulating at "Lisfranc's joint," to saw through the metatarsal bones just in front of their bases.

The **metatarso-phalangeal articulations** are situated 1 in. behind the web of the toes. In disarticulating a toe, the transverse metatarsal ligament, which unites the heads of the metatarsal bones, should not be injured.

The **tendon** of the **tibialis posticus** may be felt, and, by inverting the foot, seen, as it extends from behind the tip of the internal malleolus to the tubercle of the scaphoid; it crosses the astragalus immediately above the sustentaculum tali.

In the commonest form of club-foot, viz. *talipes equino-varus*, the tubercle of the scaphoid is approximated to the internal malleolus, so that tenotomy of the tendon should be performed through a puncture a little below the tip of the internal malleolus; if the knife, after dividing the tendon, be carried down to the bone, the **inferior calcaneo-scaphoid ligament** will be divided and the **astragalo-scaphoid joint** opened, a procedure which is called for before the foot can be brought into good position.

Crossing the front of the ankle-joint, from within outwards, are the following tendons: viz. the **tibialis anticus**, the largest and most prominent; the **extensor longus hallucis**, the **extensor longus digitorum**, and the **peroneus tertius**. The **extensor brevis digitorum** gives rise to a fleshy pad which overlies the dorsal aspect of the calcaneo-cuboid joint. When the foot is everted, the tendon of the **peroneus brevis** may be seen extending from the tip of the external malleolus to the base of the fifth metatarsal bone; immediately below it is the tendon of the **peroneus longus**, which, as it winds round the cuboid, is obscured by the fleshy fibres of the abductor minimi digiti muscle. The **abductor hallucis muscle**, although described along with the sole, forms a fleshy pad along the inner border of the foot below the sustentaculum tali.

An incision, extending from the tubercle of the scaphoid to the middle of the inner border of the heel, will expose the various tendons, vessels, and nerves, as they pass from the inner ankle into the sole beneath the abductor hallucis.

The **dorsalis pedis artery** may be mapped out on the surface by drawing a line from a point opposite the ankle-joint, midway between the tips of the two malleoli, to the hinder end of the first interosseous space; the vessel may be compressed against the inner column of the tarsal bones. The **internal saphenous vein** and **nerve** lie between the anterior border of the internal malleolus and the tendon of the tibialis anticus; the **external saphenous vein** and **nerve** take the same course as the tendon of the peroneus brevis.

The **internal plantar vessels** and **nerves** lie along the **internal intermuscular septum**, which corresponds to a line drawn from the under surface of the inner tuberosity of the os calcis to the interval between the first and second toes. The **external plantar vessels** and **nerves** may be exposed by an incision along the **external intermuscular septum**, which runs in a line extending from the middle of the under surface of the heel to the fourth toe (Kocher); to map out the course of the **plantar arch**, draw a line across the sole from the inner side of the base of the fifth metatarsal bone to the hinder end of the first interosseous space.

THE ABDOMEN.

THE ANTERIOR ABDOMINAL WALL.

The configuration of the abdomen varies with the age, sex, obesity, and muscular development of the individual. In the child it is wider above than below, while the converse is the case in the adult female. It is most prominent in the region of the **umbilicus**, which is situated, normally, below the mid-point between the infrasternal notch and the symphysis pubis, usually a little below the level of the highest part of the iliac crest, and opposite the middle of the body of the fourth lumbar vertebra. In the obese, and especially when the abdominal muscles have lost their tone, the umbilical region becomes prominent and more or less pendulous, so that the umbilicus may come to lie considerably below the normal level. In the child it is relatively lower than in the adult, in consequence of the undeveloped state of the pelvis.

In spare subjects the lower end of the body of the sternum, the xiphoid cartilage, and the costal margin, can readily be traced. The slight depression or notch

formed by the seventh costal cartilages and the lower border of the body of the sternum is termed the **infrasternal notch**. Below the notch, and bounded on either side by the seventh, eighth, and ninth costal cartilages, is the **infracostal angle**, which varies considerably according to the shape of the chest; it is relatively wider in the child than in the adult. The lower border of the curve of the **tenth costal cartilage** is easily recognisable, and has been selected by Cunningham as the level of the plane of separation (**infracostal plane**) between the upper and middle abdominal zones.

The anterior abdominal wall is limited below by the fold of the groin and the crest of the pubes. In a spare muscular subject the recti, the furrows corresponding to the **lineæ transversæ**, and the supra-umbilical portion of the **linea alba**, can be readily made out. When the outline of the rectus is not visible the outer border may be indicated by a line drawn from the tip of the ninth costal cartilage to the mid-point of a line joining the umbilicus and the anterior superior iliac spine, and from thence to the pubic spine. In the angle between the outer border of the rectus and the ninth costal cartilage, on the right side, is a slight triangular depression which overlies the fundus of the **gall-bladder**. Between the lower part of the outer border of the rectus and the prominence above the anterior part of the iliac crest, caused by the lower muscular fibres of the external oblique, is another slight triangular depression, which corresponds to the lower and narrow part of the aponeurosis of the external oblique muscle.

Close above, and almost parallel to, the inner half of Poupart's ligament is the **inguinal canal**, traversed by the **spermatic cord** (Fig. 297, p. 402); the latter can be felt to emerge at the external abdominal ring immediately above the pubic spine. The **external** and **internal abdominal rings** have been fully described elsewhere; the former is triangular in shape, with its apex directed upwards and outwards, and its base immediately above the pubic crest. By invaginating the skin of the scrotum the little finger may readily be passed through the ring into the canal. It is to be noted that the neck of an *inguinal hernia* lies above the pubic spine, whereas the neck of a *femoral hernia* emerges below the inner end of Poupart's ligament, external to the pubic spine. The **internal abdominal ring**, an opening in the fascia transversalis, lies ½ in. above a point a little internal to the middle of Poupart's ligament. The **deep epigastric artery** may be mapped out by drawing a line from a point midway between the anterior superior iliac spine and the symphysis pubis towards the umbilicus. The vessel, together with the inner third of Poupart's ligament and the lower part of the outer border of the rectus, bounds a triangle known as **Hesselbach's triangle**. As the deep epigastric artery passes upwards and inwards to disappear behind the conjoined tendon and the outer border of the rectus, it lies behind the spermatic cord immediately internal to, and below, the internal abdominal ring. The floor of Hesselbach's triangle is formed throughout by the fascia transversalis, superficial to which, over the inner half or so of the triangle, is the **conjoined tendon**. An **oblique inguinal hernia** leaves the abdomen at the internal abdominal ring and traverses the whole length of the inguinal canal; its coverings are therefore the same as those of the spermatic cord, and the neck of the sac lies external to the deep epigastric artery, hence this variety of hernia is also termed an *external inguinal hernia*. A **direct inguinal hernia**, on the other hand, instead of traversing the whole length of the inguinal canal, pushes before it that part of its posterior wall which is formed by the floor of Hesselbach's triangle. The neck of the sac, therefore, lies internal to the deep epigastric artery, and this variety of hernia may be termed an *internal inguinal hernia*. If a direct hernia makes its way through the inner part of Hesselbach's triangle, it derives a covering from the conjoined tendon as well as from the fascia transversalis; if through the outer part of the triangle, the outer edge of the conjoined tendon curves round the inner side of the neck of the sac. To relieve the constriction at the neck of the sac, in the case of an *oblique inguinal hernia*, the edge of the knife is directed upwards and outwards to avoid the deep epigastric artery, while in a *direct hernia* the artery is avoided by dividing the constriction in an upward and inward direction. In an *oblique inguinal hernia* the sac lies within the infundibuliform fascia (fascia propria of the hernia), whereas in a *direct hernia*

the fascia propria is derived from the fascia transversalis of Hesselbach's triangle. The extra-peritoneal fat which covers the outer surface of the hernial sac is sometimes hypertrophied to such an extent as to amount to a fatty tumour.

In a large proportion of children at birth the **funicular process** of peritoneum, which connects the tunica vaginalis testis with the abdominal peritoneum, especially on the right side, is still patent. Should the bowel force its way along the patent process a **congenital inguinal hernia** arises. In the majority of the cases of congenital inguinal hernia it will be found that the tunica vaginalis testis has been shut off by closure of the lower part of the funicular process, only the upper part remaining patent and forming the sac of the hernia. In regard to the operation for the cure of inguinal hernia, it should be borne in mind that in the acquired form the *hernia produces the sac*, whereas in the congenital variety the *sac is the cause of the hernia;* it follows, therefore, that in the operation for *acquired* hernia the closure of the canal is as important as the removal or obliteration of the sac, while in a *congenital* hernia the most essential part of the operation is the closure of the neck of the sac, and as the muscular and fascial apparatus forming the walls of the canal are well developed, they should be interfered with as little as possible. A patent funicular process may persist during adult life without any bowel descending into it; on the other hand, years after birth bowel may suddenly enter it. In practically all oblique inguinal herniæ, which develop suddenly in children as well as in adolescents and young adults, the *sac* is of congenital origin.

Parallel to and at the level of the outer half of Poupart's ligament is the **deep circumflex iliac artery.** In dividing the abdominal wall to reach the structures in the iliac fossæ, the incision should be made in the angle between this vessel and the deep epigastric artery. To lessen the risk of ventral hernia the muscles should be split in the direction of their fibres—the aponeurosis of the external oblique from above downwards and inwards, the muscular fibres of the internal oblique and transversalis horizontally. An incision through the abdominal wall parallel to the outer border of the rectus has the great disadvantage of dividing the **abdominal terminations of the lower intercostal nerves**, which run parallel to a line extending from the tenth costal cartilage to the umbilicus.

The middle line is the site usually selected by the surgeon to open the abdomen. The points of surgical importance to be noted in connexion with the **linea alba** are: (1) that its blood supply is scanty; (2) that it is considerably wider above than below the umbilicus, where the two edges of the recti lie in close apposition; (3) that above the umbilicus the fascia transversalis and linea alba are adherent, so that the two form practically one membrane; (4) that the extra-peritoneal fat is more abundant beneath the linea alba than to either side of it; (5) that above the pubes the fascia transversalis recedes from the linea alba, leaving a triangular space occupied by fat which must not be mistaken for the extra-peritoneal fat.

The posterior layer of the rectal sheath ceases at the **fold of Douglas**, which is situated one-third of the distance from the umbilicus to the pubes. The fleshy fibres of the transversalis muscles extend inwards for a considerable distance behind the upper part of the recti.

THE ABDOMINAL CAVITY.

To simplify the topography of the abdominal viscera the abdomen is arbitrarily divided into nine regions by two horizontal and two vertical planes. Of the two horizontal planes, the **upper (infracostal) plane** is at the level of the lowest part of the tenth costal cartilages; the **lower (intertubercular) plane** is at the level of the tubercular points of the iliac crests. The **two vertical planes** correspond upon the surface to a line drawn vertically upwards on either side from a point midway between the anterior superior iliac spine and the pubic symphysis. Superiorly, these vertical planes generally strike the tip of the ninth costal cartilages. The subdivisions of the **upper zone** are termed the *epigastric* and *right* and *left hypochondriac regions*, of the **middle zone** the *umbilical* and *right* and *left lumbar regions*, of the **lower zone** the *hypogastric* and *right* and *left iliac regions.* The epigastric,

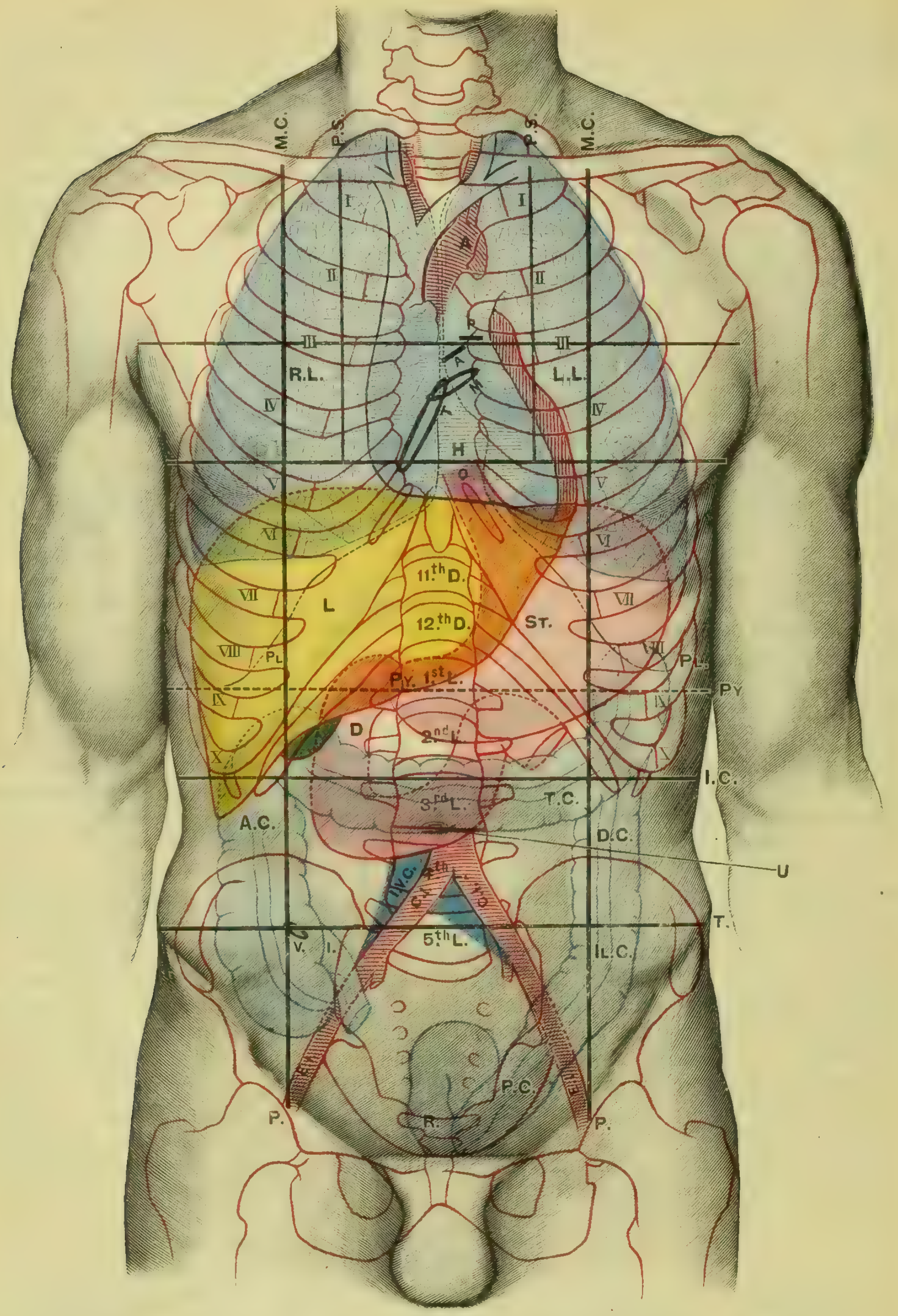

FIG. 822.—ANTERIOR ASPECT OF TRUNK, SHOWING SURFACE TOPOGRAPHY OF VISCERA.

M.C. Mid-clavicular line.
P.S. Parasternal line.
P. Poupart vertical line.
I.C. Infracostal line.
T. Intertubercular line.
Py. Transpyloric line of Addison.
A. Aorta.
H. Heart.
P. Pulmonary orifice.
A. Aortic orifice.
M. Mitral orifice.
T. Tricuspid orifice.
R.L. Right lung.
L.L. Left lung.
Pl. Pleura.
L. Liver.
O. Œsophagus.
St. Stomach.
Py. Pylorus.
D. Duodenum.
I. Ileum.
V. Ileo-cæcal valve.
A.C. Ascending colon.
T.C. Transverse colon.
D.C. Descending colon.
Il.C. Iliac colon.
P.C. Pelvic colon.
R. Rectum.
C.I. Common iliac artery.
E.I. External iliac artery.
I.V.C. Inferior vena cava.
U. Umbilicus.

umbilical, and hypogastric regions may be further divided into right and left halves by the median plane. The **xiphisternal junction** is on a level with the disc between the ninth and tenth dorsal vertebræ. The **infracostal plane** passes through the upper part of the third lumbar vertebra; the **intertubercular plane** through the fifth lumbar vertebra, about 1 in. above the sacral promontory. The umbilicus is usually situated from 1 to 2 in. above the intertubercular line.

In the method of surface topography employed by Addison the plane of separation between the superior and middle abdominal zones is placed midway between the suprasternal notch and the upper border of the pubic symphysis. It will be found to lie at or near the mid-point between the xiphisternal junction and the umbilicus. Posteriorly, this plane strikes the lower border of the first lumbar vertebra, and it so constantly passes through the pylorus that it may with advantage be termed the **transpyloric plane.**

The **peritoneal cavity** may be regarded as a large and complicated lymph sac which is intimately related to the abdominal viscera, and more especially to the gastro-intestinal canal. Inflammatory infections of the peritoneum are therefore almost always secondary to lesions of the viscera. The peritoneal lymph sac is brought into direct communication with the subperitoneal lymphatics of the diaphragm through stomata which open upon the peritoneum covering the under surface of that muscle. The healthy peritoneum, in virtue of the vital action of its endothelial cells, is endowed with great absorptive properties, and, when irritated, has the power of throwing out an abundant exudation. The reflexion of the peritoneum and its relations to the various organs have been elsewhere fully described (p. 1046).

From the surgical point of view the peritoneal cavity may be arbitrarily divided into **four great subdivisions**: viz. (1) that between the transverse mesocolon and the diaphragm; (2) that between the transverse mesocolon and the mesentery of the small intestine; (3) that between the mesentery and the true pelvis; (4) that in the true pelvis. The **lesser sac** of the peritoneum may be looked upon as a diverticulum of the first-mentioned subdivision.

The attachment of the **transverse mesocolon** to the posterior abdominal wall is at the level of the second lumbar vertebra, and lies, therefore, a little above the infracostal plane. The attachment, which ascends slightly as it passes from right to left, crosses the right kidney, the second part of the duodenum, and the head of the pancreas, after which its attachment follows the anterior border of the pancreas. The *peritoneal subdivision above this attachment* is roofed in by the diaphragm, and includes the upper part of the greater sac, and, behind it, the larger portion of the lesser sac. The organs related to this area of the peritoneum are the liver, along with the bile ducts and gall-bladder, the stomach and part of the duodenum, the spleen, the pancreas, the upper part of the kidneys, and the suprarenal capsules. Suppuration connected with any of these organs is liable to spread upwards under the cupola of the diaphragm, producing what is known as *subphrenic abscess.* The routes followed to drain this region of the peritoneal cavity are either (1) through the anterior abdominal wall and the gastro-hepatic or gastro-colic omenta; (2) through the loins below the twelfth ribs; (3) through the chest wall, the lower part of the pleural cavity, and the diaphragm, steps having been previously taken to shut off the drainage-track from the pleural cavity. This subdivision of the peritoneal cavity may become shut off from the rest of the space by adhesion of the great omentum to the peritoneum of the anterior abdominal wall.

The attachment of the **mesentery** of the **small intestine** extends from the left side of the second lumbar vertebra downwards to the right iliac fossa (Fig. 675 p. 1001). The attachment may be mapped out on the surface by drawing a line from a point on the transpyloric line, one inch to the left of the middle line, to the mid-point of a line drawn horizontally between the right anterior superior iliac spine and the middle line. The *subdivision between the transverse mesocolon and the mesentery proper* is related more particularly to the small intestine, the cæcum and vermiform appendix, the ascending colon, the right ureter, and part of the right kidney. Suppuration in connexion with the organs in this area involves

more especially the right lumbar region, and may extend upwards along the colon into the subdiaphragmatic region, or downwards into the true pelvis. To drain this region a tube is introduced into the right lumbar region either through the anterior abdominal wall or through the right loin.

The *peritoneal subdivision below the mesentery* corresponds to the left umbilical, left lumbar, and left iliac regions, and is related to the duodeno-jejunal junction, the greater part of the small intestine, part of the transverse colon, the splenic flexure, the descending colon, the iliac colon, the lower part of the left kidney, the left ureter, the lower part of the abdominal aorta, and the common iliac arteries. Suppuration in this division is very liable to extend downwards into the pelvis. Drainage may be established by the introduction of a tube either through the anterior abdominal wall or through the left lumbar region. If suppuration occur in the pelvis, drainage may be carried out through the anterior abdominal wall or, in the case of the female, through the vagina.

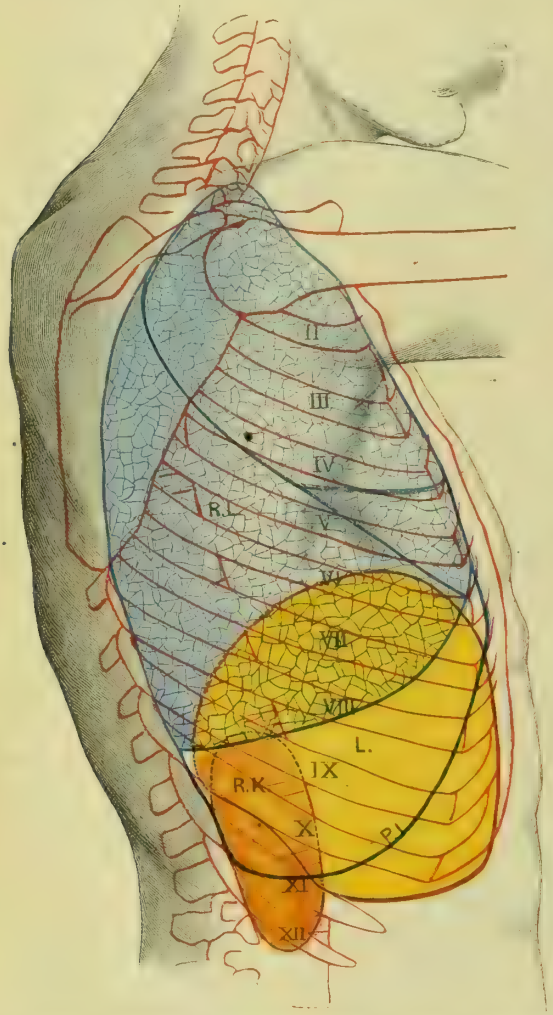

Fig. 823.—Lateral Aspect of Trunk, showing Surface Topography of Viscera.

R.L. Right lung. R.K. Right kidney.
L. Liver. P.L. Pleura.

Liver.—The *lower border of the liver*, as it crosses the costal angle, can readily be determined by palpation and light percussion; it passes from the eighth left to the tip of the tenth right costal cartilage, and crosses the mesial plane at the level of the transpyloric line. In the *mid-axillary line* it reaches down to a point a little below the lowest part of the tenth right costal cartilage. Above the left costal margin the lower border passes upwards and to the left to join the left extremity of the liver at the fifth interspace in the mammary line. The *highest part of the liver*, which corresponds also to the highest part of the right arch of the diaphragm, reaches, during expiration, the level of the fourth intercostal space in the mammary line. To the right of the mesial plane the upper border of the liver is too far removed from the anterior wall of the chest, and overlapped by too thick a layer of lung substance, to be accurately determined by percussion. *Behind the sternum* the upper border reaches to the level of the sixth chondrosternal junctions. To the left of the mesial plane the upper limit of the liver cannot be determined by percussion as it merges into the cardiac dulness. The **falciform ligament** of the liver lies, as a rule, a little to the right of the mesial plane.

The anterior surface of the liver may be reached through a mesial incision extending downwards from the ensiform cartilage, or by an oblique incision a finger's breadth below and parallel to the right costal margin. To obtain free access to the upper surface the eighth and ninth costal cartilages must be resected; the seventh cartilage should, if possible, be avoided, otherwise the pleural, and even the pericardial cavity, may be opened. Division of the round and falciform ligaments

allows of greater downward displacement of the liver. To reach the centre of the lateral surface of the right lobe portions of the seventh and eighth ribs should be resected in the mid-axillary line, and both the pleural and peritoneal cavities must be traversed.

The relation of the fundus of the **gall-bladder** to the surface is subject to considerable variation; generally it is situated opposite the angle between the ninth costal cartilage and the outer border of the rectus. The **cystic duct**, which passes downwards and forwards, is bent sharply upon itself close to its origin at the neck of the gall-bladder. The **common bile-duct**, about 3 in. in length, lies, in its *upper third*, in the right free border of the gastro-hepatic omentum; its *lower two-thirds* lie at first behind the first part of the duodenum, and then between the head of the pancreas and the second part of the duodenum, on the inner wall of which it opens a little above its termination. Fenger has shown that the *middle portion* of the common duct is that which is least closely related to the portal vein.

Stomach.—The stomach lies almost entirely within the left half of the epigastric and the left hypochondriac regions. The **cardiac orifice**, which lies 1 in. below and to the left of the œsophageal opening in the diaphragm, is about 4 in. from the surface, and corresponds, on the anterior surface of the body, to a point over the seventh left costal cartilage 1 in. from the sternum. The **pylorus**, which is generally partly overlapped by the lower margin of the liver, lies, as a rule, about 1 in. to the right of the mesial plane; when the stomach is *empty* it generally lies in the mesial plane, when *distended* it may reach two, or even three, inches to the right of the middle line. The pyloric portion of the stomach is practically bisected by a horizontal plane which passes through the abdomen at the level of a point midway between the suprasternal notch and pubic symphysis (Addison); it lies, therefore, 3 to 4 in. below the infrasternal notch, midway between it and the umbilicus, opposite the first lumbar vertebra. The highest part of the **fundus** of the **stomach** corresponds to the left vault of the diaphragm, and lies a little above and behind the apex of the heart. The **greater curvature** crosses behind the left costal margin opposite the tip of the ninth costal cartilage, that is to say, where the transpyloric line intersects the vertical Poupart line. The lowest part of the great curvature, situated generally in the mesial plane, extends down to, or a little above, the infracostal plane, about 2 in. above the umbilicus. The **lesser curvature** and the adjacent part of the anterior wall of the stomach are overlapped by the lower margin of the liver.

Overlying the stomach is an important surface area known to clinicians as the **semilunar space of Traube**. This space, which yields a deeply tympanitic note on percussion, is bounded above by the lower margin of the left lung; below, by the left costal margin; to the right, by the lower edge of the left lobe of the liver; behind and to the left, by the anterior border and anterior basal angle of the spleen. The line of the costo-diaphragmatic pleural reflexion crosses the space about midway between its upper and lower limits. The tympanitic area of the space is diminished superiorly by pleuritic effusion, towards the right by enlargement of the liver, and towards the left by enlargement of the spleen.

Perforation of an ulcer on the *anterior wall* of the stomach leads to extravasation into the greater sac of the peritoneum, while if the perforated ulcer be upon the *posterior wall*, extravasation takes place into the lesser sac. The close relation of the splenic artery and its branches to the posterior wall of the stomach explains the severe hæmorrhage which is sometimes caused by a posterior gastric ulcer. The surgeon may reach the posterior wall of the stomach through the gastro-colic omentum, or, after throwing upwards the great omentum and transverse colon, by traversing the transverse mesocolon; by the former route the posterior wall of the stomach is reached through the anterior wall of the lesser sac, in the latter case through its posterior wall.

Duodenum.—The **first part** of the duodenum, situated in the right half of the epigastrium, lies behind the eighth costal cartilage, immediately internal to the gall-bladder, and is overlapped by the quadrate lobe of the liver. If the finger be passed above this part of the duodenum and towards the left, behind the right free border of the lesser omentum, it will occupy the **foramen of Winslow**, which is

just large enough to easily admit the finger. In resecting the pylorus, the surgeon should remember that the gastro-duodenal vessels lie behind the first part of the duodenum, about 1 in. to the right of the pylorus.

The **second part** of the duodenum descends in the right vertical Poupart plane, and is crossed about its middle, at the level of the infracostal plane, by the attachment of the transverse mesocolon. It lies in front of the hilus and lower part of the inner border of the right kidney.

The *transverse portion* of the **third part** of the duodenum occupies the upper part of the umbilical region, and crosses the middle line about 1 in. above a line joining the highest part of the iliac crests; behind its commencement is the upper part of the right ureter.

The *ascending portion* of the **third part** of the duodenum crosses the infracostal plane, and ascends upon the left side of the vertebral column opposite the second and third lumbar vertebræ.

The **duodeno-jejunal flexure**, which lies in the transpyloric plane 1 in. to the left of the mesial plane, is the landmark which the surgeon makes for when he wishes to identify the commencement of the jejunum (Fig. 677, p. 1004). To find the flexure the omentum and transverse colon should be thrown upwards and the finger passed along the lower layer of the transverse mesocolon to the left side of the vertebral column. The flexure lies in the angle or recess formed by the left side of the second lumbar vertebra and the under surface of the body of the pancreas. With the finger in this recess the commencement of the jejunum may be hooked forward a little to the left of the superior mesenteric vessels at the root of the mesentery. In connexion with the duodeno-jejunal junction is the **duodeno-jejunal fossa** (inferior duodenal fossa of Jonnesco), formed by a fold of peritoneum which stretches from the left side of the fourth or ascending part of the duodenum upwards to become attached to the peritoneum of the posterior abdominal wall close to the inner border of the left kidney. The free edge of the fold and the mouth of the fossa look upwards. This is one of the situations at which an internal hernia sometimes develops, the sac, as it enlarges, extending further and further into the extra-peritoneal tissue on the posterior abdominal wall. Should strangulation occur, the lower edge of the orifice must be divided in a downward direction, in order to avoid the superior mesenteric vein which curves round the anterior and upper aspects of the orifice (Treves).

Small Intestine.—The coils of the small intestine dip downwards into the pelvis, overlap the ascending and descending portions of the colon, and extend upwards to the attachment of the transverse mesocolon. To the left of the mesentery they reach as far as the under surface of the pancreas and the splenic flexure of the colon: here they are overlapped by the lower part of the stomach, from which they are separated by the transverse mesocolon. The only certain means which the surgeon has of distinguishing the upper from the lower coils of small intestine is by their relation to the duodeno-jejunal flexure and the ileocæcal junction. Occasionally the Peyer's patches can be seen from the peritoneal aspect and the ileum thereby identified. The *terminal portion of the ileum*, which is attached by the lower end of the mesentery to the upper part of the right lateral wall of the true pelvis, crosses over its brim, and ascends along the inner edge of the cæcum before opening into it. The terminal loop of the ileum may be hooked up by passing the finger along the inner side of the cæcum downwards over the inner border of the psoas and the external iliac vessels into the pelvis.

Large Intestine.—The **cæcum**, which occupies the right iliac region, comes into contact with the anterior abdominal wall immediately above the outer third of Poupart's ligament; laterally, it extends from the anterior superior iliac spine to the brim of the pelvis. When dilated, it extends considerably beyond these limits; when empty, it is generally more or less completely overlapped by small intestine. The **ileo-cæcal valve** lies obliquely a little below the intertubercular plane, immediately internal to where that plane is intersected by the Poupart plane; it is situated, therefore, at the upper and outer angle of the right hypogastric region, opposite a point on the surface 1 in. below the mid-point of a line joining the umbilicus and the anterior superior iliac spine.

The orifice of the **appendix** opens upon the postero-internal aspect of the cæcum about an inch below the ileo-cæcal valve. The appendix will generally be found to pass either upwards and inwards behind the lower end of the ileum, or downwards and inwards so as to overhang the external iliac vessels at the brim of the pelvis; less frequently it ascends in the pouch behind the commencement of the ascending colon. The *blood supply of the appendix* is derived from a single artery (a branch of the ileo-colic) which occupies the small mesentery of the appendix; hence interference with the flow of blood along this vessel, either mechanically or from disease, predisposes to gangrene of the appendix. In exposing the appendix, the centre of the incision should be about 1 in. below and external to the mid-point between the umbilicus and the anterior superior iliac spine. The sheath of the rectus should, if possible, not be opened. After dividing the peritoneum, the appendix is sought for by passing the finger behind the angle formed by the inner aspect of the cæcum and the lower end of the ileum. It may be necessary to bring the cæcum out of the wound, in order that the anterior longitudinal band of muscular fibres (tænia coli) may be traced downwards to the root of the appendix.

The **ascending colon**, after crossing the iliac crest, lies deeply in the right lumbar region upon the quadratus lumborum and the right kidney.

The **hepatic flexure** reaches upwards beneath the tenth costal cartilage into the lowest part of the right hypochondrium, where it lies immediately to the right of the gall-bladder, between the liver and the lower half of the anterior surface of the kidney.

The **transverse colon** crosses the upper part of the umbilical region. Not infrequently it forms a U-shaped or a V-shaped loop which reaches for a variable distance below the level of the umbilicus; when the intestines are distended it may ascend in front of the stomach.

The **splenic flexure** reaches upwards behind the greater curvature of the stomach into the left hypochondriac region, as far as the lower extremity of the spleen, from which it is separated by the costocolic fold of peritoneum.

The **descending colon** lies deeply in the left lumbar region, along the lower half of the outer border of the left kidney.

The **iliac** and **pelvic portions** of the **colon** lie respectively in the left iliac fossa and in the true pelvis; the latter is provided with a distinct mesentery which, as it crosses the left ureter and the bifurcation of the common iliac vessels, forms the **intersigmoid peritoneal fossa**. This fossa is sometimes the starting-point of an internal retroperitoneal hernia. The mouth of the fossa looks downwards and to the left; above and to its right is the sigmoid artery. The iliac colon can generally be felt through the abdominal wall as it descends from the crest of the ileum to the inner margin of the psoas muscle. The iliac colon is the part of the bowel which is most frequently opened when it is desired to make an artificial anus. It is exposed through an oblique incision, the centre of which is at the junction of the middle and outer thirds of a line drawn from the umbilicus to the anterior superior iliac spine.

Kidneys.—The kidneys, which lie behind the peritoneum, extend higher up than is often supposed, and laterally they do not extend so far away from the spine as is almost invariably depicted; hence it is that, unless enlarged, the kidneys can seldom be felt through the abdominal wall. The right kidney as a rule lies a little lower than the left, as well as a little further away from the mesial plane. The hilus of the right kidney lies 2 in. from the mesial plane; that of the left $1\frac{1}{2}$ in. from the mesial plane. For practical purposes the **hilus** of the kidney may be regarded as opposite a point on the anterior abdominal wall a finger's breadth internal to the tip of the ninth costal cartilage; and a line joining the two hili crosses the vertebral column opposite the disc between the first and second lumbar vertebræ, that is to say, on a level with the transpyloric line. The *highest point* of the kidney is situated two inches from the mesial plane, on a level with a line crossing the abdomen midway between the xiphisternal and transpyloric planes. The *lowest point* of the kidney reaches down to, or a little below, the infracostal plane.

The student should make himself familiar with the feel of the parts in relation to the kidneys, as far as they can be made out by introducing the hand through a mesial abdominal incision. The lower half of the **right kidney** is covered by the

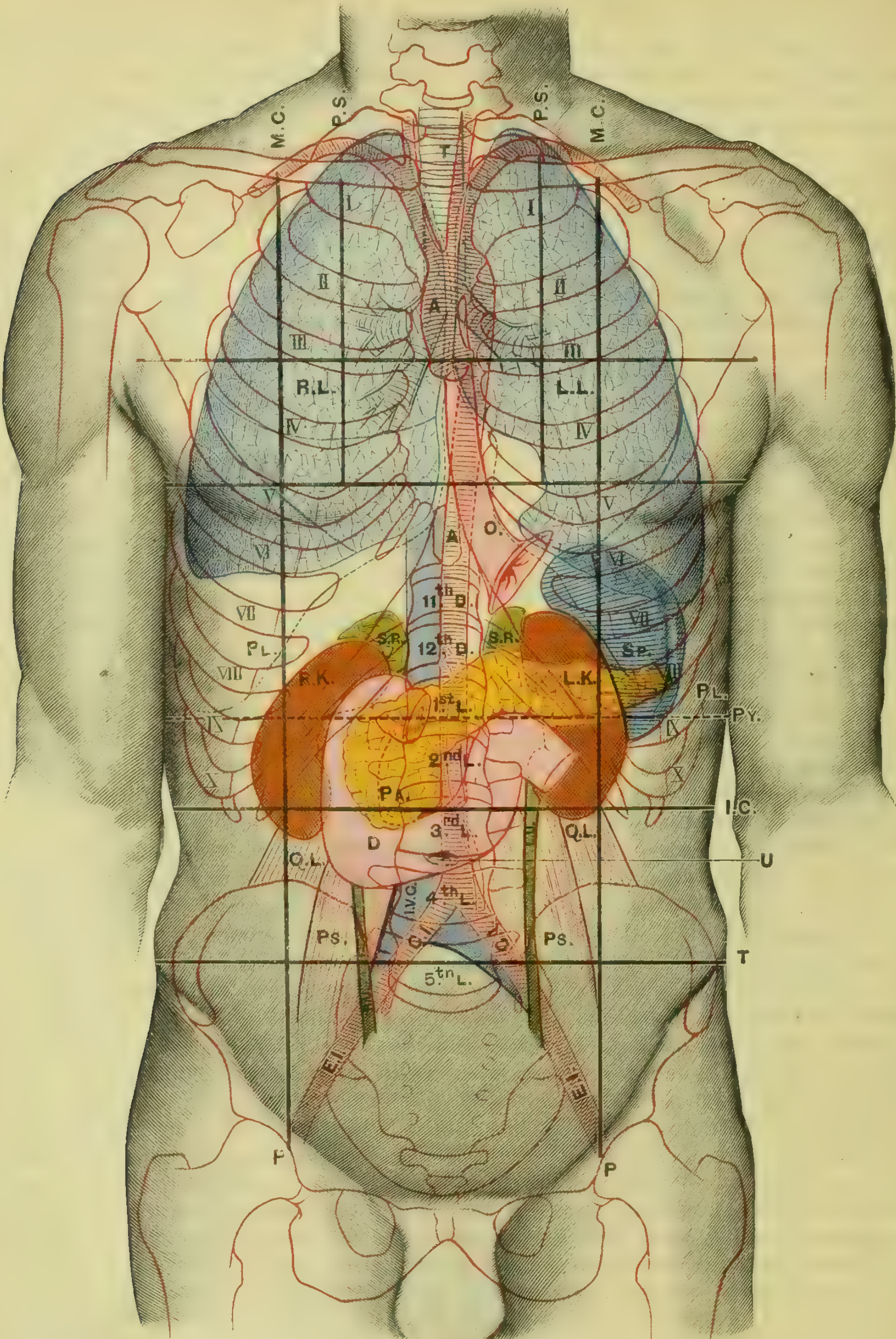

FIG. 824.—ANTERIOR ASPECT OF TRUNK, SHOWING SURFACE TOPOGRAPHY OF VISCERA.

M.C.	Mid-clavicular line.	L.L.	Left lung.	Q.L.	Quadratus lumborum.
P.S.	Parasternal line.	Pl.	Pleura.	Ps.	Psoas.
P.	Poupart vertical line.	O.	Œsophagus.	R.U.	Right ureter.
Il.	Infracostal line.	R.K.	Right kidney.	L.U.	Left ureter.
T.	Intertubercular line.	L.K.	Left kidney.	C.I.	Common iliac artery.
Py.	Transpyloric line.	Sp.	Spleen.	E.I.	External iliac artery.
T.	Trachea.	S.R.	Suprarenal capsule.	I.V.C.	Inferior vena cava.
A.	Aorta.	Pa.	Pancreas.	U.	Umbilicus.
R.L.	Right lung.	D.	Duodenum.		

hepatic flexure of the colon; the upper part lies deeply in the hypochondrium, and is felt by thrusting the hand upwards and backwards between the liver and the hepatic flexure of the colon. Between this part of the kidney and the renal surface of the liver is a deep recess which receives its serous covering from peritoneum continued upwards from the upper layer of the transverse mesocolon. Overlapping the hilus and the lower part of the inner border is the descending part of the duodenum, which is crossed by the transverse colon.

The lower half of the **left kidney**, covered by peritoneum continued downwards from the lower layer of the transverse mesocolon, is easily felt in the hollow between the vertebral column and the upper part of the descending colon. It is overlapped by coils of small intestine, and passing transversely outwards in front of it is the left colic artery and its branches. Crossing the left kidney, a little above its middle, is the body of the pancreas, together with the splenic vessels. To reach the part of the kidney which lies above the pancreas, an opening should be made through the gastro-colic omentum and the hand passed upwards behind the stomach into the lesser sac of the peritoneum. Applied to the upper half or more of the outer border of the kidney is the renal surface of the spleen.

The posterior relations of the kidneys have been referred to when dealing with the back.

Outside the true capsule of the kidney is the **adipose capsule**, which is a specialised thickening of the extra-peritoneal fat. It is in this fat that a perinephritic abscess develops, the pus passing backwards into the loin, downwards towards the iliac fossa, or forwards into the extra-peritoneal fat of the anterior abdominal wall.

The **ureters** lie behind the peritoneum covering the psoas muscles; they descend almost vertically in the umbilical region $1\frac{1}{2}$ in. from the mesial plane. At the level of the intertubercular plane they lie in front of the termination of the common iliac arteries, and then pass down into the true pelvis in front of the internal iliac arteries.

Pancreas.—The *head of the pancreas* occupies the curve of the duodenum, and lies in the lowest part of the right half of the epigastric region, on a level with the second lumbar vertebra. The *neck*, which crosses the mesial plane opposite the disc between the first and second lumbar vertebræ, lies in the transpyloric plane, while the body lies immediately above that plane. The *tail* lies in the left hypochondriac region. The relations of the pancreas to the transverse mesocolon and to the neighbouring viscera have already been sufficiently referred to.

A pancreatic cyst gives rise to a tumefaction of the abdomen either in the epigastric or in the umbilical region, depending on whether it pushes the gastro-hepatic omentum before it and develops between the liver and stomach, or whether it extends forwards below the stomach. In severe contusions of the abdomen the pancreas may be ruptured against the vertebral column.

Vessels of the Abdomen.—The commencement of the **abdominal aorta** and the **cœliac axis** is situated two fingers' breadth above the transpyloric plane. The **superior mesenteric** artery arises a finger's breadth above the transpyloric plane, the **renal arteries** a finger's breadth below it. The **inferior mesenteric artery** arises midway between the transpyloric and the intertubercular plane—that is to say, about 1 in. above the level of the umbilicus. The **abdominal aorta** bifurcates in, or a little to the left of, the mesial plane, on a level with the highest part of the iliac crest, and about $\frac{3}{4}$ in. below the level of the umbilicus.

The **inferior vena cava** lies immediately to the right of the aorta; its most important surgical relation is the right ureter, which lies close to its outer side.

The **common** and **external iliac arteries** may be mapped out by drawing a line, curved slightly outwards, from a point opposite the bifurcation of the aorta to a point midway between the anterior superior iliac spine and the pubic symphysis: the upper third of this line corresponds to the common iliac, the lower two-thirds to the external iliac. The **common iliac veins** lie mainly to the right of the corresponding arteries, the left vein, however, crossing behind the right artery to join its fellow to form the inferior vena cava. The relation of the veins and of the ureters must be borne in mind in ligaturing the common iliac arteries.

The great vessels upon the posterior abdominal wall, along with the adjacent lymphatic vessels and glands, lie in the extra-peritoneal fat, and therefore within the general fascial envelope of the abdomen. Abscesses originating from the retro-peritoneal lymphatic glands are, therefore, like perinephritic abscesses, extra-peritoneal, but intra-fascial; abscesses of spinal origin, whether lumbar, iliac, or psoas, are, on the other hand, extra-fascial. Abscesses connected with the vermiform appendix are primarily intra-peritoneal; occasionally they ulcerate through the parietal peritoneum and burrow in the extra-peritoneal fat.

THE MALE PERINEUM.

The male perineum is a heart-shaped space the osseous boundaries of which are the same as those which form the outlet of the pelvis. A line drawn transversely across the perineum between the anterior part of the tuberosities crosses the middle line immediately in front of the anus, and divides the space into an anterior or urogenital triangle and a posterior or rectal triangle. The **urogenital triangle** is subdivided into a superficial and deep compartment by the triangular ligament; in the superficial compartment is the root of the penis, which gives rise to a longitudinal fulness upon the surface. Anteriorly, the surface of the urogenital triangle is continued on to the scrotum, whilst laterally a distinct groove separates it from the inner surface of the thighs. The **central point** of the **perineum** (common tendon of the perineal muscles) is continuous with the centre of the base of the triangular ligament, and lies a finger's breadth in front of the anus. Immediately in front of it, and about 1 in. from the centre of the anus, is the posterior edge of the **bulb** of the **corpus spongiosum**. The *superficial compartment* of the urogenital triangle is bounded below by the **perineal fascia of Colles**, which is attached posteriorly to the base of the triangular ligament, and laterally to the margins of the pubic arch. Anteriorly, the fascia of Colles passes on to the scrotum, the penis, and spermatic cord, to become continuous with the **fascia of Scarpa** upon the front of the abdomen.

When the urethra is ruptured below the anterior layer of the triangular ligament, the course of infiltration of extravasated urine is determined by these attachments; at first, therefore, the urine is confined within this compartment, but gradually travels forwards under the fascia of Colles on to the lower part of the anterior abdominal wall; it is prevented from passing down the front of the thigh by the attachment of Scarpa's fascia to the fascia lata, a little below Poupart's ligament.

The *deep compartment* of the urogenital division of the perineum corresponds to the interval between the triangular ligament proper and the parietal layer of the pelvic fascia (the so-called superior or deep layer of the triangular ligament). The most important structures which this compartment contains are the membranous portion of the urethra, Cowper's glands, the internal pudic vessels, and the artery to the bulb.

The **membranous part** of the **urethra** lies 1 in. behind the lower border of the pubic symphysis. When this division of the urethra is ruptured, the extravasated urine, after filling the deep compartment, may reach the superficial compartment by bursting through the triangular ligament where the vessels pierce it; or it may penetrate the parietal layer of the pelvic fascia, infiltrate the perivesical connective tissue and the space of Retzius, and ultimately ascend in the anterior abdominal wall between the fascia transversalis and the parietal peritoneum.

Cowper's glands, which lie immediately behind the membranous urethra, are overlapped by the bulb of the urethra, from which they are separated by the triangular ligament. The **internal pudic artery** lies just within the margin of the pubic arch. The **artery to the bulb** runs transversely inwards $\frac{1}{4}$ in. above the base of the triangular ligament, *i.e.* above the level of a line drawn from the front of the tuberosities to the central point of the perineum.

The **male urethra** measures about 8 in. from the external to the internal meatus; the narrowest portion is at the external meatus; a second narrowing occurs at the triangular ligament. It is behind these constrictions that a calculus

is liable to become impacted. The *most dependent part* of the urethra is the bulbous portion, and it is in this situation that an organic stricture is most frequently met with. The membranous portion of the urethra, situated between the two layers of the triangular ligament, is surrounded by the compressor urethræ muscle, which, when thrown into spasm, may firmly grip an instrument as it is passed into the bladder. *Rupture of the urethra* from a fall on the perineum generally involves the bulbous portion. A *false passage* made during the passage of an instrument generally traverses the floor of the urethra at the triangular ligament; to prevent this the point of the instrument should always be directed upwards, and the handle at the same time depressed as soon as the instrument is felt to encounter the resistance of the triangular ligament. When the *prostate is hypertrophied* the prostatic portion of the urethra is elongated, and the internal meatus may look directly forwards, while if the lateral lobes are unequally enlarged it may deviate laterally. Patients with prostatic hypertrophy are seldom able to completely empty the bladder, on account of the dependent well which exists below and behind the prostate.

The **epididymis**, which can be felt behind the testicle as an elongated curved body applied vertically to its posterior surface, is especially involved in gonorrhœal and tubercular infections of the testicle. Occupying the posterior part of the spermatic cord is the **vas deferens**, which, when grasped between the finger and thumb, feels like a piece of whip-cord. The **spermatic veins** form a plexus in the substance of the cord, known as the pampiniform plexus; a varicose condition of these veins gives rise to the condition known as *varicocele.* In operating for varicocele the veins are reached by dividing in succession all the coverings of the cord; the deepest covering, viz. the infundibuliform fascia, derived from the fascia transversalis, forms a well-marked fibrous envelope which immediately surrounds the veins and other constituents of the cord. Besides the spermatic artery, the testicle receives its blood supply from the artery accompanying the vas deferens and from the cremasteric branch of the deep epigastric.

The marked swelling which attends *œdema and hæmatoma of the scrotum* is due to the loose and delicate character of the cellular tissue which occupies the space between the dartos muscle and the subjacent membrane derived from the intercolumnar fascia.

The **anus** is situated in the rectal division of the perineum about 1½ in. in front of and below the tip of the coccyx. The skin around the orifice is pigmented and thrown into radiating folds. The painful linear crack or ulcer, known as *fissure of the anus,* generally occupies one of the furrows at the posterior margin of the anus. The skin of the anus is provided with large sebaceous and sweat glands, which are occasionally the site of small and very painful anal abscesses.

On making a *rectal examination* it will be observed that the finger, before it reaches the cavity of the rectum, traverses the narrow or sphincteric portion of the rectum, appropriately named by Symington the **anal canal**. This canal, which is directed from below upwards and forwards, extends from the anal orifice to the ampulla of the rectum, is about 1 in. in length; its upper end is on a level with the inner borders of the pubo-rectal portions of the levatores ani.

External hæmorrhoids are developed from the anal folds situated outside the white line corresponding to the muco-cutaneous junction; *internal piles* are developed from the veins of the mucosa at the upper part of the anal canal.

In the upper half of the anal canal are the **valves of Morgagni**. According to Ball, fissure of the anus is generally caused by the tearing downwards of one of the posterior valves during the passage of a scybalous mass.

According to Birmingham, the pubo-coccygeal fibres of the levator ani close the upper part of the anal canal, whilst the external sphincter closes the remaining part. The internal sphincter, according to the same author, acts probably as a detrusor, its use being to empty the anal canal completely after the passage of each fæcal mass.

The apex of the **ischio-rectal fossa**, formed by the attachment of the anal fascia to the obturator portion of the parietal pelvic fascia, is directed upwards towards the pelvis, and lies 2½ in. from the surface. The inner wall of the fossa is

bounded by the levator ani and coccygeal muscles covered by the anal fascia; the outer wall by the obturator internus muscle covered by the obturator fascia. An *abscess in the ischio-rectal fossa* should be opened early, otherwise it is liable to burst through the inner wall into the rectum; should it open also upon the skin surface a complete "*fistula in ano*" is formed. When a "fistula in ano" results from the bursting of a submucous abscess of the anal canal the track of the fistula runs either internal to or through the fibres of the internal and external sphincter muscles, and the external or skin opening is, as a rule, close to the anus, while the internal opening is generally within the upper end of the anal canal. Occasionally the ischio-rectal abscess perforates the levator ani towards the apex of the fossa; it then burrows into the peri-rectal cellular tissue of the pelvis, and opens into the ampulla of the rectum. In other cases, again, the abscess starts in the peri-rectal tissue internal to the levator ani, and either bursts into the rectal ampulla or through the levator ani into the ischio-rectal fossa, and so reaches the surface. Or the pus may burrow between the rectum and coccyx, whence it may pass outwards through the great sacro-sciatic foramen behind the parietal pelvic fascia into the buttock; or, by piercing the visceral layer of the pelvic fascia, may reach the extra-peritoneal fatty tissue of the pelvis and ascend in it to form an iliac abscess.

The *lymphatics* from the anus pass along the perineo-crural folds to the innermost glands of the groin, both inguinal and crural. From the rectum the majority of the lymphatics pass through a chain of glands which lie alongside the superior hæmorrhoidal vessels in the retro-rectal cellular tissue in front of the sacrum; others, accompanying the middle hæmorrhoidal veins, go to the glands in the neighbourhood of the internal iliac vessels.

In making a *rectal examination* the finger should be carried forwards from the tip of the coccyx so as to enter the anus from behind. The finger is then gently pressed upwards and slightly forwards through the sphincteric region in the axis of the anal canal until it reaches the cavity of the rectum, the lower part of which is dilated to form the ampulla. The folds or valves of Houston, three in number, project into the cavity of the bowel in the form of prominent crescentic shelves, which are produced by the three permanent or true flexures into which the rectum is thrown (Birmingham); the lower valve, which may be sufficiently prominent to impede the passage of the finger, must not be mistaken for a pathological condition. Through the anterior wall the finger can palpate from below upwards the bulb of the urethra, the membranous parts of the urethra, Cowper's glands (when inflamed and enlarged), the apex and lateral lobes of the prostate, the vesiculæ seminales (when diseased), and the external trigone of the bladder. With the left forefinger in the rectum, an instrument passed into the bladder can be distinctly felt as it traverses the membranous urethra; as it lies in the prostatic urethra it is separated from the finger by the prostate. Hence, when a *false passage* is made through the bulbous or membranous portion of the urethra, the instrument, if pushed onwards towards the bladder, will be felt immediately outside the rectum between it and the prostate. In the child, owing to the rudimentary condition of the prostate, the instrument is distinctly felt close to the rectum, as it lies in the prostatic as well as in the membranous portion of the urethra. When the prostate is not enlarged the tip of the finger can just reach the external trigone, which is most distinctly felt when the bladder is full. The vesiculæ seminales, indistinctly felt when healthy, may be readily palpated when enlarged and indurated from disease. Through the lateral wall of the rectum may be palpated the ischio-rectal fossa, the bony wall of the true pelvis, and, when enlarged, the internal iliac lymphatic glands; through the posterior wall the hollow of the sacrum and coccyx, and the lymphatic glands lying in the retro-rectal cellular tissue.

In the child rectal examination enables one to palpate, in addition to the structures in the cavity of the true pelvis, those which occupy the lower segment of the abdomen. When the bladder is empty even a small calculus can be readily felt by recto-abdominal palpation.

The distance of the apex of the **recto-vesical pouch** of peritoneum from the anus varies considerably, according to the degree of distension of the bladder and rectum; when both are empty it reaches to about 2 in. from the anus; when both are distended it is at least one inch higher. As pointed out by Birmingham, the peritoneum is closely adherent to the rectum above and in front, while at the side and below the connexion is much looser, so that by stripping the peritoneum

upwards the greater part, or even the whole, of the rectum may be excised without opening into the peritoneal cavity.

The posterior surface of the **prostate**, the **vesiculæ seminales**, and the **external trigone of the bladder**, may be exposed by making a transversely curved incision, convex forwards, between the two ischial tuberosities. The centre of the incision passes through the central point of the perineum, immediately behind the bulb, while laterally the incision sinks into the ischio-rectal fossa behind the transverse perineal muscles and the base of the triangular ligament. By dividing the anterior or pubo-rectal fibres of the levatores ani the lower part of the rectum is exposed, and may be readily separated from the recto-vesical layer of the pelvic fascia. On dividing this fascia the posterior surface of the prostate is exposed, and above it the external trigone of the bladder, bounded laterally by the vesiculæ seminales and the terminal portions of the vasa deferentia.

FEMALE PELVIS.

The external genitals are fully described at page 1136. The external **orifice** of the **urethra**, surrounded by a slight annular prominence of the mucous membrane, is situated about 1 in. behind the clitoris, immediately above the centre of the base of the vestibule—a smooth triangular area at the anterior part of the vulva, with its sides formed by the labia minora and its base by the anterior margin of the ostium vaginæ. In passing the *catheter* the instrument is directed along the forefinger (introduced just within the ostium vaginæ with the palmar surface towards the symphysis pubis) to the base of the smooth vestibule, where it is tilted slightly upwards so as to bring its point opposite the meatus.

Bartholin's glands, about the size of a bean, are placed one on either side of the posterior third of the orifice of the vagina, above the triangular ligament. Their ducts, nearly 1 in. in length, open posteriorly between the hymen and the posterior commissure (*fossa navicularis*). Abscesses and cysts not infrequently develop in connection with these glands. The **bulbs of the vagina** are two pyriform collections of erectile tissue situated one upon each side of the vestibule, between the sphincter vaginæ and the anterior layer of the triangular ligament. Rupture of these bodies gives rise to the condition known as *pudendal hæmatocele.*

In making a *vaginal examination* the patient should be placed in the dorsal position, with the thighs well flexed; the index-finger of the right hand is now carried along the fold of the buttock towards the middle line, where it will impinge against the posterior aspect of the **introitus vaginæ**, whence it is inserted upwards and backwards into the canal; to render the examination more thorough the middle finger may also be introduced. When the uterus is in its normal position the **vaginal portion of the cervix uteri** is felt as a knob-like body projecting downwards and backwards into the upper part of the canal. In nulliparæ the os uteri is a small transverse slit, whereas in women who have borne children it is larger and more or less fissured. Above and behind the cervix is the **posterior fornix**, which is in close proximity to the **pouch of Douglas**; this pouch, though normally empty, is the frequent site of displaced abdominal and pelvic organs, and collections of intraperitoneal effusions and exudations. A loaded rectum can be detected through the vagina by the characteristic way in which the contents can be pitted by the finger. In front of the cervix is the shallow **anterior fornix**, through which may be felt the body of the uterus and the base of the bladder, while through the lower half of the anterior vaginal wall the **urethra** may be detected as a cylindrical, cord-like thickening which may be rolled against the lower border of the symphysis. The **ureter**, especially if enlarged, can be recognised through the antero-lateral fornix, by compressing it against the pubic bone.

By the *bimanual examination* the pelvic organs are steadied and pushed downwards towards the pelvic outlet by the pressure of the left hand applied in the hypogastric region, so that they can be more readily reached and palpated by the finger placed in the vagina with its palmar aspect directed upwards. The **ovary** may be felt as a firm body about the size of the end of the thumb by pushing the fingers well up into the lateral fornix towards the lateral wall of the pelvis. In health the ovaries are freely movable. The healthy **Fallopian tubes** cannot, as a rule, be felt per vaginam.

The whole of the **interior** of the **bladder** in the female can be readily seen by reflecting

light into it through a speculum introduced into the empty bladder after dilating the urethra. The patient is placed in the genu-pectoral position, so that the bladder may become inflated with air, the coils of intestine being displaced upwards. In the distended condition of the bladder the mucosa has a dull white appearance, except in the region of the trigone, which shows a pale pink injection; when the bladder is contracted the mucosa appears injected throughout. The **ureteral orifices**, placed about one inch apart and connected by a slight transverse ridge (inter-ureteric fold), present the appearance of fine transverse slits situated upon small and somewhat injected elevations of the mucosa. Every minute or so a jet of urine will be seen to issue from the orifice. Having in this way located the ureteral opening, a catheter or bougie may be passed into it along the speculum.

By rectal examination the finger can palpate, from below upwards, the recto-vaginal septum, the cervix uteri, the posterior fornix of the vagina, the apex of the pouch of Douglas, and the body of the uterus. By washing out the rectum and introducing a speculum into the bowel, with the patient in the genu-pectoral position, the rectum becomes inflated with air; the finger can now feel very distinctly the posterior surface of the uterus and the Fallopian tubes, and by running the finger outwards along the prominent fold formed by the utero-ovarian ligament the ovary is also very distinctly felt.

On opening the abdomen by a mesial incision extending from the umbilicus to the pubes, and looking into the pelvis from above after displacing some coils of the small intestine upwards, the **fundus** of the **uterus**, directed forwards and a little upwards, is seen resting upon the postero-superior surface of the bladder. Behind the uterus is the rectum, and between the two the **pouch of Douglas**, containing the pelvic colon and the lower part of the ileum. The **ovary** lies a little below the level of the brim of the pelvis upon a triangular shelf, bounded in front by the broad ligament, behind and internally by the utero-sacral ligament, and behind and externally by the pelvic wall. When the vermiform appendix overhangs the brim of the pelvis its tip may come into close relation with the right ovary, a condition which often leads to a difficulty in distinguishing an inflammation of that ovary from appendicitis. The **round ligaments** are seen passing forwards and outwards from the anterior aspect of the cornua of the uterus to the internal abdominal rings, which lie immediately in front and to the inner side of the terminations of the external iliac arteries. Below and at the inner side of the round ligament, as it leaves the pelvis, is the **deep epigastric artery**. By pulling the uterus upwards the attachments of the **broad ligament** to the floor and lateral walls of the pelvis are brought into evidence, as also are the utero-vesical and recto-vaginal peritoneal pouches; the former is shallow, while the deepest part of the latter covers the upper fourth of the posterior wall of the vagina, and comes into relation, therefore, with the posterior fornix.

The **ureter** crosses the brim of the pelvis in front of the bifurcation of the common iliac artery $1\frac{1}{2}$ in. external to and a little below the centre of the sacral promontory. The corresponding point on the anterior abdominal wall is at the junction of the outer and middle thirds of a line joining the anterior superior spines of the ilium. After crossing the termination of the common iliac artery from without inwards the ureter curves downwards and forwards behind the peritoneum of the postero-lateral wall of the true pelvis; in front of it are the Fallopian tube and ovary. Before reaching the bladder it enters the parametric connective tissue, in which it curves downwards, forwards, and inwards about three-quarters of an inch external to the lateral aspect of the cervix uteri.

The **uterine artery** in the first part of its course runs downwards and forwards a little external to the ureter; at the level of the internal os it curves inwards in front of the ureter and then divides into uterine and vaginal branches.

In the operation of *hysterectomy* care must be taken not to injure the ureter; it is important, therefore, to keep in mind its relation more especially to the uterine artery and to the cervix uteri.

The **ovarian artery** enters the pelvis between the layers of that portion of the broad ligament known as the **infundibulo-pelvic ligament**; it is here that the vessel may be most readily ligatured in abdominal hysterectomy, and in ovariotomy.

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